25X1A Approved EdA Scale 1200 2/01/11 - CLA-RDP80-009264001400040002-2 CENTRAL INTELLIGENCE AGENCY REPORT NO INFORMATION REPORT CD NO. 25X1A Return to COUNTRY USSR DATE DISTR. 12 Sep 1949 **SUBJECT** Evaluation of article: Hydraulic Resistance of NO. OF PAGES 1 Columns Packed with a Granulated Catalyst PLACE NO. OF ENCLS. **ACQUIRED** (LISTED BELOW) 25X1A DATE SUPPLEMENT TO ACQUIRED BY SOURCE REPORT NO. 25X1X DATE OF INFORMATION Summary of Paper: 1. Hydraulic Resistance of Columns Packed with a Granulated Catalyst, BA Zakharov and AV Frost, Izvestiya Akademii Nauk, SSSR, Otdelenie Tekhnicheskikh Nauk, 1946, 421-39 constitutes a discussion of the Chilton-Colburn and Zhavoronkov formulae used for the determination of the hydraulic resistance of a tower packed with catalyst, and derivation of a third formula for the same purpose, which is held by the authors to be more advantageous than the other two. General Evaluation: 2. The type of operation and the catalysts referred to in this article are those frequently employed in the refining industry, thus making the discussion pertinent. This is a mathematical discussion and only after a thorough study of the mathematics involved and perhaps also after verification of the experimental data given could an evaluation of the importance of this contribution be made. the work is well done. 25X1X 3. Other Commenta: 25X1X 4° AV Frost, the second of these authors He has previously published a considerable amount of good research on thermodynamics and related subjects He must be regarded as a reliable research worker. 25X1A end -CLASSIFICATION RESTRICTED/US OFFICIALS ONLY

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Petroleum Sechnology

HYDRAULIC RESISTANCE OF COLUMNS
PACKED WITH A GRANULATED CATALYST
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25X1A

August 26, 1949 (r)

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IZVESTIYA AKADEMII NAUK 3SSR, OTDELENIE TEKHNICHESKIKH NAUK (Bulletin de l'Acedemie des Sciences URSS, Classo des Sciences Techniques) 1946, 421 - 39 FUB

This is a complete translation of the original article.

CONCLUSIONS

- 1. The formula of Chilton and Colburn gives too low values for the dependence of the hydraulic resistance upon the average grain size and the linear rate of flow of the gas, and gives incorrect values for the dependence of the hydraulic resistance upon the diameter of the column; this formula is unsuitable for calculation of the hydraulic resistance of a column packed with a granulated catalyst.
- 2. The formula of Zhavoronkov, based on an analysis of extensive experimental material is suitable for calculations, but does not directly indicate the effect upon the hydraulic resistance of the grain size of the catalyst and the diameter of the column.
- 3. An equation is suggested which is based on the formula of Zhavoronkov and is suitable for the calculation of the performance of a catalytic column; it characterizes the hydraulic resistance of the column with respect to three elements, i.e., gas flow (linear velocity, density, kinematic viscosity of the gas); granulated catalyst (average grain diameter); dimensions of the column (altitude, diameter).

In many branches of the chemical industry, especially those in which heterogeneous catalytic and adsorption phenomena are made use of, as well as in the fuel and petroleum technology, the value of the hydraulic resistance exerted by a layer or centact column packed with granulated material is important. It is possible to estimate and to compare the hydraulic resistance exerted by the walls of a catalytic tower, the surface of the granules of the packing and the entire column, as well as to determine the extent of the effect upon the hydraulic resistance of the average diameter of the grains of the catalyst, the diameter of the column and the linear velocity of the gas.

h

Hydraulic Resistance of Empty Towers

The hydraulic resistance of catalytic columns without the packing can be calculated by the formula of d'Arcy

$$\triangle 1 / \sqrt{2}G$$

$$\triangle F = \frac{2d}{2d}$$
/1/

where $\triangle p$ is the loss of pressure in kg./sq.m., \nearrow is the density of the gas in kg. sec. $^2/m^2$, \overline{w} is the average linear velocity of the gas in m./sec, $\triangle 1$ is the length and d the diameter of the column in meters, G the coefficient of resistance, depending upon the Reynolds number Red = \overline{w} d/ \sim , in which γ is the coefficient of the kinematic viscosity in sq. m./sec.

For a streenline flow (Red less than 2,320)

$$G = \frac{64}{Re_d}$$
 /la/

while for a turbulent flow ($Re_{\tilde{d}}$ more than 2,320) the coefficient of resistance can be expressed, depending upon the Reynolds number, as follows: At $Re_{\tilde{d}}$ from 3,000 to 100,000, according to the law of Blasius

$$G = \frac{0.3164}{\text{Red}^{0.25}}$$
 /2/

At Re_d from 10^5 to 3×10^6 , the formula given by Nikuradze can be made use of:

$$G = 0.0032 + \frac{0.221}{Re_d 0.237}$$
 /3/

To determine the order of magnitude of the hydraulic resistance of a contact column without a catalyst, comparative calculations were carried out by the authors. Air served as the viscous medium and its temperature was 15 and 500°. The column consisted of a single tube or identical tubes (for instance, 180 tubes per column). In one case the altitude of the column was 1 m., diameter 0.1 m. In the second case the altitude was 2.544 m., the diameter 0.2 m. The rate of flow of air by weight is connected with the linear velocity by the relationship $\phi=3600~\rm v_0s$ m γ , where ϕ is the rate

of flow in kg./hr., vo linear velocity in m./sec., so cross sectional area of the tube in sq. m., m number of tubes in the column, and γ specific gravity of the air for the given temperature. The rate of flow so determined changed within 2.28 and 18,304 kg./hr. The physical parameters for air given by Kirpichev et al (1) were used. The results of the calculations for an empty column are shown in Table 1 for given conditions of performance of this column. This table shows that the resistance of the column walls to the gas flow is quite small as compared to that exerted by the surface of the catalyst grains.

Hydraulic Resistance of Packed Columns

On the basis of analysis of experimental data, Chilton and Colburn suggested (2) a formula for the calculation of the hydraulic resistance of columns packed with granulated material. Perry gives (3) this formula in the metric system as follows:

$$\Delta p = \frac{202 f^0 e v_0^2 L}{D_g}$$
 /4/

In this formula $\triangle p$ is the pressure drop in kg./sq. m. due to the hydraulic resistance, \mathbf{v}_0 the linear velocity in m./sec., through the tube, L the thickness of the layer of packing in meters, \mathbf{D}_g average diameter of a grain of the packing in mm., \mathbf{f}^0 the resistance coefficient depending upon the modified Reynolds number $\mathbf{Re}^1 = \mathbf{D}_p \mathbf{v}_0 \gamma / \mathbf{z}$, in which γ is the specific gravity of the gas in kg./cu. m., and \mathbf{z} is the coefficient of viscosity in centipolaes: $\mathbf{z} = \mu \mathbf{g}$. Here μ is the coefficient of viscosity in kg. sec./sq. m., \mathbf{g} acceleration due to gravity in m./sec.², \mathbf{c} a factor which is a function of the ratio $\mathbf{D}_p/\mathbf{D}_{tube}$; \mathbf{D}_p is the average diameter of the particle in meters, defined as a mean arithmetical value of three sizes, while \mathbf{D}_{tube} is the diameter of the tube in meters.

A calculation of c and f^o is quite difficult and inexact if attempted graphically. For this reason mathematical expressions were derived by the authors for the dependencies $f^o=f({\rm Re}^{\, {}_{}})$ and $c=f(\frac{D_p}{D_{\rm tube}})$, based on the graphs given by Perry.

Fig. 1 shows two curves characterizing the first of these dependencies. Curve 1 refers to streamline conditions, while curve 2 refers to turbulent conditions. The critical value of the Re' number is 44.1 The points on the curves give values found from this graph, and the curves correspond to the obtained equations. For the streamline flow (Re' less than 44.1)

$$f_{\text{str}}^{\circ} = \frac{912}{Ref} ; \qquad /5/$$

for turbulent flow (Re' more than 44.1)

$$f_t^0 = \frac{30.2}{86!0.1}$$
 /6/

Fig. 2 shows two curves for the dependence $c=f(D_p/D_{tube})$. The points on the curve also indicate values graphically found and the curves correspond to equations obtained. The curves for both conditions consist of two parts described by different equations. The critical value, again D_p/D_{tube} , is 0.037. For streamline flow (curve 1) the following are valid: For D_p/D_{tube} less than 0.037

$$c_{str} = \frac{0.838}{\frac{D_{p}}{0.03384}}$$
 /7/

and when this ratio is more than 0.037

$$c_{str} = \frac{0.604}{\frac{D_{p}}{D_{tube}}}$$
 /8/

For the turbulent flow (curve 2) the case of $D_{\rm p}/D_{\rm tube}$ less than 0.037 is represented by equation

$$c_{t} = \frac{0.732}{\frac{D_{p}}{D_{tube}}}$$

$$(\frac{D_{p}}{D_{tube}})$$

while, when the value of D_p/D_{tube} is more than 0.037

$$c_{t} = \frac{0.424}{D_{p} \stackrel{0.22}{\sim} 22}$$

$$\frac{D_{tube}}{D_{tube}}$$

In 1944 Zhavoronkov published (4) a study of the hydraulic resistance of scrubbers packed with solid granulated material, which constitutes a part of his doctoral dissertation (5). The experimental data are generalized as follows:

$$\triangle \rho = \frac{2f' \rho v_0^2 H}{D_e v_{free}^2}$$
 /11/

where $\triangle \beta$ is the hydraulic resistance in kg./sq. m.; \mathbf{v}_0 is linear velocity in m./sec., calculated for the complete cross section of the empty tube; H, altitude of the packed tube in meters; / density of the air in kg. $\sec^2/m.4$; f', coefficient of resistance which depends upon the Reynolds number

$$Re = \frac{d_{\Theta}v_{O}}{\sqrt{v_{free}}}$$

y being the coefficient of kinematic viscosity in sq. m./sec., de the equivalent diameter of the tube in meters, v_{free} the free volume of the packing. For streamline flow at values of the Reynolds number less than 40 to 50, f' = 100/Re. For an unstable turbulent flow within the Reynolds numbers from 50 - 5,000, f' = 3.8 Re^{-0.2} and, finally, for a stable turbulent flow at Reynolds numbers above 5,000, f' will be independent of Re and amount to 0.7

$$d_{e} = \frac{\sqrt[4]{\text{tube}} \sqrt[8]{\text{free}}}{s_{\text{tube}}}$$

where V_{tube} is the volume of the packed tube in cubic meters, s_{tube} the total surface which exerts the hydraulic resistance, square meters, i.e., s' * s". Here s' is the surface of the granules of the packing and s" the surface of the wall of the tube.

For a cylindrical tube

$$s'' = TD_{tube}H$$
, $s' = s_3n$ $n = \frac{(1 - v_{free}) V_{tube}}{V_3}$

where n is the number of particles in the packing, s3 and v3 are the average surface and the average volume of a granule of the packing, respectively. For calculation of the hydraulic resistance of the packed contact

column by the Zhavoronkov formula, it is necessary to determine experimentally the values of n, s_2 , v_{free} , in addition to knowing the values of the basic parameters of the column and of the gas stream.

By correlation of the values of the free volume, experimentally determined by Zhavoronkov and by the present authors for different granulated packings (Table 2), with the value of the average grain size, the dependence shown in Fig. 3 was established.

In Fig. 3 points on the curve correspond to experimentally determined values of the free space of the catalyst bed and the average particle diameter, and the curve is represented by

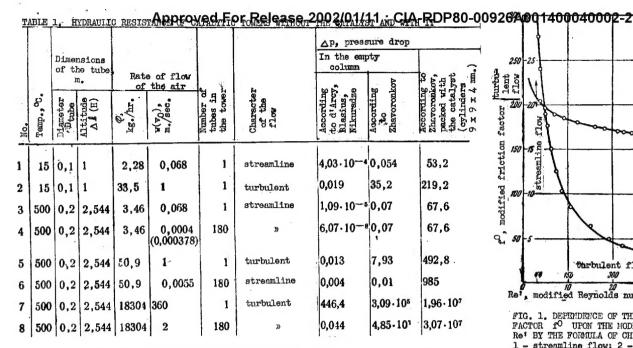
$$v_{\text{free}} = 0.222D_{\text{g}}^{0.252}$$
 /12/

Dependence of the Hydraulic Resistance of a Column Upon the Average Diameter of the Catalyst Grain

It is quite important to find whather there is any interdependence between the hydraulic resistance of the contact column and the average diameter of the grain size. For this purpose calculations were carried out by the authors, using the formulas of Chilton and Colburn and of Zhavoronkov, respectively. A particular case was considered under the following conditions: Diameter of the column, 0.2 m; altitude, 2.544 m.; air temperature, 500° ; linear velocity of the air in the streamline flow region, 0.068; that under turbulent conditions, 1 m./sec.; $\rho = 0.0459$ kg. sec. $^2/m$. 4 ; $^{\prime}/m = 8.0410^{-5}$ sq. m./sec.; $\gamma = 0.45$ kg./cu. m.; z = 0.03617 centipoises; average grain diameter within 0.004 and 0.0127m. The catalyst was shaped into cylinders.

The results are shown in Fig. 4, where the dots represent calculated values and the curves mathematical expressions derived. Figs. 4 and 3 characterize streamline flow corresponding to the formulas of Chilton and Colburn and of Zhavoronkov. Curves 1 and 2 refer to turbulent flow and the first of these is based on the Chilton and Colburn formula, the second on the Zhavoronkov formula. For streamline flow the following expression corresponds to the Chilton and Colburn formula:

$$\triangle p_{c.c.} = \frac{0.001667}{p_{p}^{2.076}}$$
 /13/



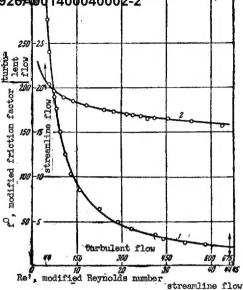


FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR f^O UPON THE MODIFIED REYNOLDS NUMBER Re † BY THE FORMULA OF CHILTON AND COLBURN. 1 - streamline flow: 2 - turbulent flow

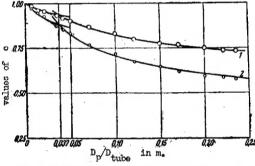


FIG. 2. DEFENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS $\bf c$ UPON THE RATIO OF THE AVERAGE DIAMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE $\bf c$ Dy $\bf d$ The FORMULA OF CHILTON AND COLBURN. Dp/Dtube 1 - for streamline flow; 2 - for turbulent flow

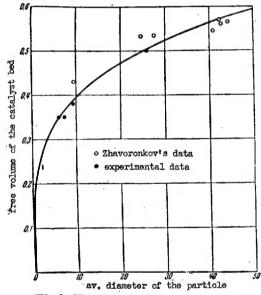


FIG. 3. DEPENDENCE OF THE FREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES.

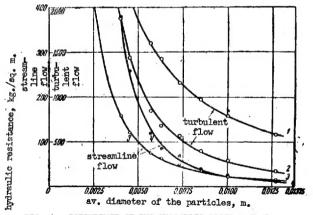


FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED $\Delta\,_{\rm P}\,$ UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov. For streamline flow: 3 - according to Zhavoronkov; 4 - according to Chilton and Colburn.

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE

- 11		DIAMETER OF THE	GRAIN		
No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diam- eter of the grain, mm.	Free space
1* 2* 3	Glass rods Aluminosilicate catalyst Catalyst for con- version of CO Vanadium catalyst	Cylinders Cylindrical tablets Tablets	5×5×8 9×9×4 11×11×6 11×11×6,5	6,0 7,3 9,3	0,35 0,35 0,38
5 6* 7 8	Coke Glass granules Coke "	Irregular Pear-shaped Irregular	$\begin{array}{c} 29.6 \times 25.8 \times 18 \\ 20 \times 20 \times 37.5 \\ 35.6 \times 28.8 \times 18 \\ 47.6 \times 41.5 \times 33.4 \end{array}$	24,5 25,8 27,5 40,8	0,532 0,500 0,538 0,548
9 10 11	Gravel Coke Andesite	Spherical Irregular	$\begin{array}{c} 56,8 \times 40,8 \times 29 \\ 52 \times 40,3 \times 35,5 \\ 56 \times 43,7 \times 32,6 \end{array}$	42,2 42,6 44,1	0,570 0,560 0,565

Izv. (tekh.) 1946, 421 ff.



The expression corresponding to the Zhavoronkov formula /11/ is given by:

$$\triangle P_{\text{zh}} = \frac{1.866 \times 10^{-5}}{D_{\text{p}}^{3.044}}$$
 /14/

The interrelationship of these expressions for small values of the average particle diameter, below 0.0065, is

$$\triangle P_{gh} = 3 \triangle P_{c.c.} - 100$$
 /15/

while for values above 0.0065 it is:

$$\triangle p_{zh} = 1.49 \triangle p_{c,c} - 9$$
 /16/

For turbulent flow the following obtain:

$$\triangle p_{c.c.} = \frac{2.6}{p_p^{1} 2 \lambda_1}$$
 /17/

$$\triangle p_{2h} = \frac{0.016}{D_p^2.116}$$
 /18/

The equations 17 and 18 can be combined as follows:

$$\triangle p_{zh} = 0.0038 \triangle p_{c.c.}^{1.68}$$
 /19/

Dependence of the Hydraulic Resistance of a Column Packed with Granulated Catalysts Upon its Diameter

Inasmuch as the basic equations under discussion show no clear connection between the hydraulic resistance of the contact column and its diameter, this problem was also considered in the study under report. The conditions and parameters of the principal hydrodynamic values were in the main the same as for the expression $\triangle p = f(D_p)$ discussed before. The difference consists in the values of D_p and D_{tube} . The average grain diameter was constant, 0.0073 meters. v_{free} was 0.359. Silica-alumina catalyst was



used, shaped as cylindrical tablets, $9 \times 9 \times 4$ mm. The diameter of the catalyst column, consisting of a single tube, varied from 0.04 to 0.7 meters.

Fig. 5 shows the results of the calculation for particular cases, based on the formulas of Chilton and Colburn /4/ and of Zhavoronkov /11/. The four curves shown each consist of two branches corresponding to the mathematical expressions for the dependency $\triangle p = f(D_{\text{tube}})$ for tubes with small or large diameters. The points represent values calculated by the formulas /4/ and /11/.

The formula of Chilton and Colburn for streamline conditions is represented by the curve 4. The critical value of the tube diameter is 0.162. At smaller values

$$\triangle P_{e.c.} = 2.363D_{tube}^{0.1343}$$
 /20/

For cases where the diameter exceeds 0.162

$$\triangle p_{c.c.} = 1.992D_{tube}^{0.035}$$
 /21/

The curve 2 is valid for the regions of turbulent flow. At values of the tube diameter below 0.2042

$$\triangle p_{c.c.} = 1663D_{tube}^{0.221}$$
 /22/

and for diameters exceeding 0.2042, the relationship

$$\triangle p_{\text{c.c.}} = 12870_{\text{tube}}^{0.0568}$$
 /23/

Data pertaining to the hydraulic resistance of columns with granulated packing as a function of the column diameter obtained with the aid of the Zhavoronkov formula, are represented by the curves 3 and 1. The first of these refers to streamline conditions, the second to turbulent conditions. For tubes with a small diameter, i.e., below 0.074

$$\triangle P_{\rm sh} = \frac{31.9}{00.3158}$$
 /24/

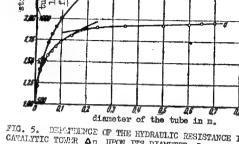


FIG. 5. DEPITIENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYTIC TOWN Ap UPON ITS DIAMETER Date. The curves 1 and 3 were calculated according to Zhavoronkov and curves 2 and 4 according to Chilton and Colburn.

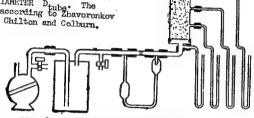


FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LINEAR VELOCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST

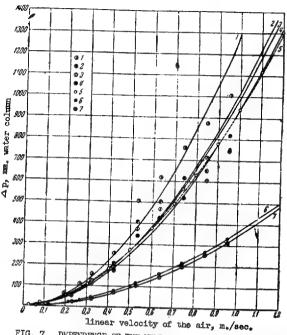


FIG. 7. DEPETEDENCE OF THE HYDRAULIC RESISTANCE Δp OF ACCOUNT WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY. OF THE GAS STREAM OBSERVED IN THIS WORK. I - Δp at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; 4 - Δp at the exit from the column; 5 - Δp according to Ehavoronkov; 6 - Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn; assuming the average diameter of the particles to be equal to the cubic root of three

TABLE 3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT COLUMN (D $_{\rm bube}$) ON THE VALUE OF K IN EQUATION P/46/

	t ··· -	b	CONTACT COLUMN (Dtube) Or	N THE VALUE OF K IN	EQUATION P/46/	STER OF THE					
	-			was consideration of the con-	Value	of K in equation	/16/				
No.	Flow	Interval of values of Dtube Dp	Interval of values of Dp for known Dtube, m	Interval of values (in m.) of Dtube for	From Dp of the	from D.	11be				
-		1	1	D _p = 0.0073 m.	entire interval	given for the interval	Values of K corresponding to them				
1	turbulent	> 470	for D _{tube} = 0,7 M < 0,0015	> 3,43	3D p 0,085	(7; 4)	(2,64; 2,97) 1 0 tube 0,04				
2	»	470-77	0,0015-0,009	3,43-0,562	2,11 D _p 0,03	(3; 0,8)	(2,22; 2,12) $\frac{1}{D_{\text{tube}^{0,04}}}$				
3	10	77—25	0,009-0,0028	0,562-0,182	1,38 I	(0,5; 0,2)	$(1,35; 1,33) \frac{1}{L_{-0}^{0.04}}$				
5	3	25—12	for 0,0028—0,0583 —Для Dто 0,04 м	0,182-0,087	$1,16 \frac{1}{D_{\rm p}^{0,100}}$	(0,15; 0.09)	(1,05; 1,06) 1 D _{tube} 0,04				
6	1 0	12-2,3	0,0033-0,017	0,087-0,017	3,08 D _p 0,202	(0,07; 0,018)	(3,2; 3,14) 1 1 tube 0,211				
1	streamline	<2,3	>0,017 for D _{tube} = 0.07 M	< 0,017	17,62 D _p 0.629	(0,017; 0,003)	(8,5)* I cube 0.28 8				
		>100	<0,0005-0,0073 (0,0005-0,0073)	> 0,73	51,38 D _p 0 12	(3; 0,8)	(51,9; 49) 1 tube 0,036				
2	*	< 100	> 0,0073 (0,0073-0,05)	< 0,73	$17,6 \frac{1}{D_{0}0.098}$	(0,7; 0,06)	(16,6; 17,67) 1 tube 0.056				
3)D	8-3	for D tube = 0,01 m 0,005-0,015	0,058-0,222	85,6 D _p 0.878	(0,05; 0,02)	(85;89) tube 0,813				
1	- m	3-1,2	0,015-0,034	0;022-0,0087	600 D _p 0,839	(0,03; 0,008)	(165.2)* — 1				
	* The numerical value of Approved For Release 2002/01/11: CIA-RDP80-00926A001400040002-2 (165,2)* 1 tube 0,428										

while those with a larger diameter

$$\triangle P_{\rm zh} = \frac{62.7}{100.056}$$
 /25/

In the case of the turbulent flow (curve 1) the critical value of the diameter of the column for the conditions and parameters discussed is 0.138. For smaller diameters of the column the equation

$$\triangle \mathfrak{I}_{2h} = \frac{374}{00.211}$$
tube

was derived, while for diameters exceeding 0.138, the equation

$$\triangle P_{\rm Sh} = \frac{525}{D_{\rm tube}^0}$$
 /27/

is valid.

The mathematical expressions 20 - 27 for the determination of the effect of the diameter of the column on the hydraulic resistance, which were obtained by using the formulas of Chilton and Colburn and of Zhavoronkov are mutually related as follows (Fig. 5). For streamline flow at diameters of the tube smaller than 0.065

$$\triangle P_{ah} = -110.7 \triangle P_{c.c.} + 256.5$$
 /28/

and diameters larger than 0.065

$$\triangle \rho_{\text{sh}} = -32.3 \triangle P_{\text{c.c.}} + 128.4$$
 /29/

For turbulent flow at diameters of the tube below 0.117

$$\triangle P_{\text{sh}} = -0.7164 \triangle P_{\text{c.c.}} + 1324$$
 /30/

and at diameters larger than this value, the relationship

$$\triangle p_{\text{sh}} = -0.222 \triangle p_{\text{coc}} + 817 \qquad /31/$$

obtains.

Effect of Rate of Gas Flow Upon the Hydraulic Resistance of Columns Facked with Granulated Catalysts

In this work most attention was concentrated on the effect of the rate of the gas flow on the hydraulic resistance of contact columns, inasmuch as the basic formulas under discussion here contain a value representing the rate of flow and taken to the degree of 1.8 for the region of turbulent flow. This problem was subjected to additional experimental study. *

The linear velocity of the air varied in these experiments within 0.064 and 1 m./sec. Thus, the regions of streamline and turbulent flows were covered. The general appearance of the experimental unit is shown in Fig. 6. The metallic catalytic tower of 0.1 m. diameter and 1 m. height had two branches and was closed on both sides with lids with welded-on pipes. The catalyst,

shaped into cylinders $9 \times 9 \times 4$ mm. and $D_p = 0.0073$ m.; $V_{free} = 0.359$, was charged into the tube to form a layer 1 m. thick. The vertical layer of the catalyst was supported by a thin wire metallic grating with mesh 3×3 mm. Four glass U-tubes served as manometers indicating the pressure at the inlet at 0.25 and 0.5 m. from the inlet and at the exit. Air was charged at 15° with the aid of a powerful blower, and in order to create a stable flow it was first passed through a large tank, then through a glass kerosene flow meter with a set of diaphragms and into the bottom of the vertical catalyst tower. All communication lines were no smaller than 20 mm. in diameter. The pressure indicated by all the manometers was registered after the air flow reached stability at a given velocity. All parts of the unit were airtight.

A set of seven curves is shown in Fig. 7, which describes the experimental data partaining to the dependence of the hydraulic resistance of the catalyst layer 1 m. high upon the rate of flow of air and the results of calculations with the aid of the formulas /4/ and /11/ used before. **

As before, the points correspond to determined or calculated values, while the curves were drawn in accordance with the mathematical expressions derived. Curve 1 reflects the pressure drop at the inlet to the catalyst columniat (pressure drop of the air stream between the inlet and 0.25 m./from the inlet). The equation for this case is:

$$\triangle P_{\text{inlet}} = 1288 v_0^{1.948}$$
 /32/

This work was carried out in 1942 in the Laboratory of Motor Fuels of the Institute of Mineral Fuels, Academy of Sciences, USSR.

^{**} Air at 15° was considered to have $\gamma = 1.385$; z = 0.018 $\rho = 0.125$ $\nu = 1.43$ x 10°5 Approved For Release 2002/01/11 : CIA-RDP80-00926A001400040002-2

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For the middle of the column (at the height of 0.5 m.)

$$\triangle P_{\text{middle}} = 1012v_0^{1.901}$$
 /33/

which is represented by curve 2. The pressure drop at the exit from the catalyst column (hydraulic resistance of the layer 1 m. thick) is represented by the curve 4 based on the equation

$$\triangle P_{\text{exit}} = 935.4 v_0^{1.891}$$
 /34/

Curve 3 gives the average value of the hydraulic resistance

$$\triangle p_{\text{average}} = 984v_0^{1.873} \qquad /35/$$

which is an average of the values shown by the curves 1, 2 and 4. It should be noted that the scattering of the points observed for high air velocity is connected with a certain degree of inexactness in the flow meter scale, which is built on extrapolated values. The curve 5 joins points calculated by the formula /11/ of Zhavoronkov for the experimental conditions and parameters used in this study and is described by two equations. The critical value of the rate of flow is 0.1122. For streamline conditions where vois loss than 0.1122

$$\triangle P_{\rm sh} = 158.5 v_{\rm o} \qquad /36/$$

The region of turbulent flow with $\mathbf{v_0}$ exceeding 0.1122 is characterized by the equation 37. Formula /4/ of Chilton and Colburn is represented by the points of the curve 6 for the conditions used here. The critical value is 0.039 m./sec. The streamline section of the curve can be expressed by the equation 38.

$$\triangle p_{\rm zh} = 9312v_0^{1.8}$$
 /37/

$$\triangle p_{\text{c.c.}} = 52.5 v_{\text{o}} \qquad /38/$$

The section of the curve describing the turbulent conditions, that is, where $v_{\rm o}$ exceeds 0.089, is described by the equation

$$\triangle p_{\text{c.o.}} = 359.7 \text{v}_0^{1.8}$$
 /39/

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For the sake of comparison, the curve 7 was drawn from data obtained by the Chilton and Colburn formula for the case where the average grain diameter is a cubic root of three dimensions.

The values of the pressure drop in the air flow passing through the catalytic column according to Zhaverenkov /36/ and /37/, and according to Chilton and Colburn /38/ and /39/, are connected between themselves and with the average values of the pressure drop established by the present authors /35/ as follows:

$$\triangle p_{ah} = 2.6 \triangle p_{c \cdot c} \qquad /40/$$

$$\triangle p_{\rm zh} = 0.9352 \triangle p_{\rm even} * 21.6$$
 /41/

$$\triangle P_{c.c.} = 0.3697 \triangle P_{aver.}$$
 /42/

The pressure drop at the inlet /32/ and at the exit /34/ from the contact column is connected with the average value /35/ as follows:

$$\triangle P_{\text{inlet}} = 1.3 \triangle P_{\text{aver}}$$
 /43/

$$\triangle P_{\text{avit}} = 0.944 \triangle P_{\text{aver}}$$
 /44/

The pressure drop of the air at the inlet /32/ into the column is expressed according to Zhavoronkov /36/ and /37/ as follows:

$$\triangle P_{\text{inlet}} = 1.437 \triangle P_{\text{zh}} - 6 \qquad /45/$$

General Discussion

It is of interest to compare the values of hydraulic resistance of catalytic columns, empty as well as packed, and to appraise the effect of the number of tubes in a collector contact column upon the hydraulic resistance. The numerical values are given in Table 1. The hydraulic resistance of the empty catalytic column, as dependent upon the Reynolds number, was calculated by the formula of d'Arcy /1/ and /1a/ for streamline conditions (cases 1, 4 and 6). For turbulent conditions the law of Blasius /2/,(cases 2, 5 and 8) and the formula of Nikuradze /3/ (case 7) were made use of. Considering that the Zhavoronkov formula has two members which describe, respectively, the hydraulic resistance caused by the surface of the walls of the column and the surface of the grains of the catalyst, the question can be answered whether this formula permits a correct evaluation of the hydraulic resistance of the



empty column. For this column the following is valid for streamline conditions:

$$\triangle p_{\text{str.}} = \frac{200 \rho \gamma v_{\text{o}} H}{D_{\text{tube}}^2 v_{\text{free}}^3}$$

For the turbulent region the following obtains:

$$\triangle p_{t} = \frac{7.6 \rho \gamma^{0.2} v_{o}^{1.8} II}{D_{tube}^{1.2} v_{free}^{3}}$$

As follows from Table 1, the hydraulic resistance of the empty catalytic tower calculated by the Zhavoronkov formula has a considerably higher value for all cases under consideration here (100 - 1,000 times), as compared with the value obtained with the aid of hydrodynamic formulas widely employed in practice. It is possible, therefore, to conclude that the hydraulic resistance of empty catalytic columns cannot be calculated from the Zhavoronkov formula. For packed catalytic columns the hydraulic resistance, as calculated from the Zhavoronkov formula, is represented in the last column of Table 1. The catalyst consisted of cylindrical tablets 9 x 9 x 4 mm., of average diameter 0.0073 m. and free volume 0.359. By correlating the values of the hydraulic resistance in the empty and catalyst-packed columns, one observes that the hydraulic resistance of the columns with the catalyst exceeds the resistance of empty columns 100,000 times or more. Hence, the hydraulic resistance to the gas flow exerted by the walls of the contact column is quite negligible.

In commercial practice catalytic columns are of a special value, made up of a bundle of tubes of the same diameter. In streamline flow and at a constant value of the weight rate of gas flow, a change in the number of tubes in a packed column of this type exerts no effect upon the resistance of the column. The linear velocity is used in the equation for hydraulic resistance in the first degree; consequently for the cases 3 and 4 in Table 1, the following will be valid:

$$\frac{\triangle P_4}{\triangle P_3} = \frac{mv_4}{v_3} = \frac{mv_4}{mv_4} = 1$$

because $v_3 = v_1 m$ (m is the number of tubes in the column). A totally different situation obtains in the regions of turbulent flow. Here the linear velocity is used in the formula in the degree of 1.8. Discussing the cases numbers 8 and 7 of Table 1, it is seen that, inasmuch as the weight rate is constant, $v_7 = mv_8$:

$$\frac{\triangle p_8}{\triangle p_7} = \frac{\frac{1.8}{\text{mv}_8}}{(\text{mv}_8)^{1.8}} = \frac{1}{\text{m}^{0.8}}$$

The hydraulic resistance of a catalytic collector column decreases in proportion to the number of tubes taken to the degree of 0.8; consequently, if the technology of the process is connected with high rates of flow by weight of the gas in the region of turbulent flow, and the value of the hydraulic resistance exerted by the catalyst or the dimensions of the column do not permit to realize these velocities in the column, consisting of a single tube, then in order to remove these hindrances a collector catalytic column should be used with a number of tubes equal to the ratio of the linear velocities for a simple and a collector column. (Thus, for the cases 7 and 8 of Table 1, $\frac{v_7}{v_8}$ 180).

The effect of the average grain diameter upon the hydraulic resistance is described qualitatively by the Chilton and Colburn formula /4/ and that of Zhavoronkov /11/. The hydraulic resistance of the catalytic power drops with increase of the grain size. The Chilton and Colburn formula gives for both hydrodynamic conditions a lower drop of the hydraulic resistance of the column with increase of the average grain size, as compared to the Zhavoronkov formula. An exception is presented by some cases in the streamline region, where $D_{\rm tube}/D_{\rm p}$ exceeds 30. Here a reverse situation obtains and the Chilton and Colburn formula shows a larger drop in the hydraulic resistance, with increase of the grain size as compared to the data given by the Zhavoronkov formula. The connection between the two formulas with respect to the dependence $\Delta p = f(D_{\rm p})$ is a straight line for streamline conditions (/15/ and /16/) and an exponential for turbulent conditions (/19/).

A very interesting result was obtained by the authors in the study of the effect of the diameter of the contact column upon the hydraulic resistance. According to equations /20/ through /27/ and Fig. 5, the two formulas show contrasting effects of the diameter of the catalytic column upon the



hydraulic resistance. With increase of the diameter of the catalytic column the hydraulic resistance for both hydrodynamic conditions increases, according to Chilton and Colburn, but drops according to Zhavoronkov. The connection between the two formulas is straightline in character (equations /28/through /31/).

Ey correlating the quantitative interpretation of the dependence of the hydraulic resistance of the catalytic columns with the granulated packing upon the linear velocity of the gas stream, average grain size and diameter of the column, as expressed by the Chilton and Colburn and Zhavoronkov formulas, the following characteristic of the Chilton and Colburn formula is obtained: In \triangle p = f(v_o) considerable lowering of the values of \triangle p is noted; for \triangle p = f(D_p) a considerable decrease of the value of \triangle p and, finally, in \triangle p = f(D_{tubs}) a totally abnormal character of the functional dependence, as compared to conventional concepts is manifested.

Additional calculations of the dependence of the hydraulic resistance of columns packed with granulated catalyst upon average grain size of the packing and diameter of the column, which were based on the Zhavoronkov formula, made it possible to write a general formula embracing all principal factors which determine the performance of catalytic towers. These factors characterize the contact column (altitude H, diameter $D_{\rm tube}$), the granulated catalyst (average grain diameter $D_{\rm p}$) and the viscous medium N (where N is the product obtained by multiplying the density p, kinematic viscosity p and the linear velocity of the gas $\mathbf{v}_{\rm c}$):

$$\triangle p = \frac{KNH}{D_p^{m6}D_0^{n_0}}$$
 /46/

The hydraulic condition of the performance of the catalytic column determined the exponent of the components of N. For streamline conditions $N_{\rm str} = \rho \, \nu \, v_{\rm o}$, while for turbulent conditions $N_{\rm t} = \rho \, \nu \, v_{\rm o} \, v_{$

the catalyst (d_e) was substituted by the average grain diameter D_p , which is valid when D_{tube} considerably exceeds the value of D_p .

In order to compare the value of K in equation /46/ and the extent of the effect upon it of $D_{\rm p}$ and $D_{\rm tube}$, additional calculations were performed.



For this purpose into the Zhavoronkov formula /ll/ intermediate values were included, and it was connected with equation /46/. The values of $m_{\rm c}$ and $n_{\rm c}$ were taken from the corresponding particular expressions with consideration of the value of $\frac{D_{\rm tube}}{D_{\rm p}}$. For the streamline conditions $m_{\rm c}$ for $D_{\rm p}$ was

taken from equation /14/, no for D tube from equations /24/ and /25/; for the turbulent flow mo from equation 18/ and no from equations /26/ and /27/.

Catalyst grains had uniformly the shape of a cylinder, with a ratio of the diameter to the altitude $D_3=2h_3$, unlike the varying ratios of D_3/h_3 when particular expressions for the dependencies $\triangle p=f(D_p)$ and

 \triangle p = f(D_{tube}) were to be found. In the determination of the effect upon the coefficient K in the equation /46/ of the average grain diameter D_p, the latter was changed within 0.0005 to 0.05 m. at D_{tube} values of 0.7 and 0.04 m. In the determination of the effect on K of the diameter of the cylindrical catalyst tower consisting of a single tube, the value of D_{tube} was changed within 7 and 0.008 m., while the value of D_p was kept constant at 0.0073 m. The free volume of the catalyst bed for various values of D_p was determined from equation /12/.

The results of the calculations are given in Table 3. The values obtained for $K=f(D_p)$ and $K=f(D_{tube})$ should be introduced into equation /46/. The equation

$$\triangle p = \frac{K_0 NH}{D_p^m D_{tube}^n}$$
 /47/

will finally be obtained. The numerical values of K_o and those of the exponents of D_p and $D_{\rm tube}$ are shown in Table 4. These values differ

and refer to a definite region of values of D_{tube}/D_p and to the prevailing hydraulic conditions.

The value of K_o in equation /47/ is a physical factor of the order of magnitude m, which has so far not yet been determined. For streamline conditions it is close to 1; for turbulent conditions, of the order of 0.8.

Concerning the effect upon hydraulic resistance of the geometrical form of the granulated catalyst, which will affect the coefficient Ko in the equation /47/, two groups of geometrical forms can be considered, within



TABLE 4. NUMERICAL VALUE OF K AND OF m AND n IN EQUATION /47/ FOR DIFFERENT INTERVALS OF THE RATIO OF THE DIAMETER OF THE TUBE TO THE AVERAGE DIALETTER OF THE PARTICLE

No.	Flow		Interval of	Numerical	Values of		
	raha ayi xameekda kolaasiyoo darka galaasii ka aayaa kabo saa ii qaba ka baba ka saasa kasa ka saasa ka baba k		D _{tube} /D _p	value of Ko	m for Dp	n for D _{tube}	
1 2 3 4 5 6	turbulent " " " " " "	• •	> 470 470 - 77 77 - 25 25 - 12 12 - 2.3 < 2.3	3.00 2.11 1.38 1.16 3.08 8.50	2.030 2.086 2.176 2.225 1.914 1.487	0.040 0.040 0.040 0.040 0.211 0.430	
1 2 3 4	streamline	c •	$ \begin{array}{c} 100 \\ 100 \\ 8 - 3 \\ 3 - 1.2 \end{array} $	51.33 17.60 85.60 165.20	2.924 3.142 2.670 2.205	0.056 0.056 0.316 0.742	

which the ratio of the surface of the grain to its volume s_3/v_3 and consequently K_0 will be constant: I. cylinders of $h_3=0.5D_3$ and a longer cylinder of $h_3=2D_3$; and further, II. a regular cylinder $(h_3=D_3)$, a cube and a sphere. Here h_3 and h_3 are, respectively, the altitude and the diameter of the grain in meters.

For an appraisal of the effect of the dimensions of the grain D upon the connection of K with the geometrical form, the value of D was varied in size 100 times in the calculations performed, keeping the diameter of the catalytic column constant at 0.7 m. The results are shown in Table 5. The dimension of the grain D does not markedly affect the relationship between Ko and the geometrical form of the grain. For the group II, lower values of Ko were obtained, and for streamline conditions a more considerable drop of Ko is observed, 20% as compared to 10% for turbulent flow. Thus, a more compact geometrical form of the grain, i.e., a regular cylinder, a cube or a sphere, exerts a smaller hydraulic resistance to a gas flow than a longer form (group I).

TABLE 5									
	Conditions								
D _p , m.	Streamline				Turbulent				
AT No COLD - THE RESIDENCE OF THE RESIDENCE OF THE PROPERTY OF	0.0005	0.005	0.05	0.0005	0.005	0.05			
Ko, I group	20.65	26.47	23,60	1.57	1,80	1.60			
K _o , II "	16.18	20.98	18.77	1.40	1.61	1.44			
△K ₀ , %	21.6	20.7	20.4	11.1	10.7	10.6			

The formulas of Chilton and Colburn /4/, of Zhavoronkov /11/ and of the present author /47/ describe the interdependencies as applied to a uniformly granulated catalyst, i.e., to a catalyst consisting of granules of uniform dimensions, forming a narrow fraction of material by sieve analysis.

Hydraulic Resistance of Nonuniform Granulated Material

For the sake of completion, the hydraulic resistance of a catalyst column or layer consisting of non-uniform granulated material should be discussed. For the case of the gas flow through a layer of sand, L. S. Leibenson modified (6) the formula of Slichter (7) for flow of water, and obtained the following expression:

$$\frac{p_1^2 - p_2^2}{p} = \frac{1920 \text{ pk k}_m^{\text{H}}}{\alpha \text{ cFd}_{\text{ed}}^2}$$
 /48/

Here p_1 and p_2 are respectively the pressure at the inlet to the layer and exit from it given in kg./sq. m.; $p = \gamma RT$ in absolute atmospheres (1 kg./sq. cm.) Q = consumption of gas in cu.m./sec.; p = coefficient of

viscosity in kg. sec./sq. m.; a and $k_m = \text{coefficients}$, the second of which depends upon the relative porosity; $k_i = \text{thickness}$ of the layer in meters; $k_i = \text{specific gravity}$ of the gas with respect to air; $k_i = \text{cross-sectional area}$ of the layer in sq. m.; $k_i = \text{def}$ average effective diameter of a sand particle in mm.

$$d_{\text{ef}}^2 = \frac{1}{100} \sum_{i=1}^{\infty} \frac{\psi_i}{d_i^2}$$

where d_i is the diameter of the sand particles and \$\psi\$ i weight per cent of individual fractions.

Using the experimental data of the Institute of lineral Fuels pertaining to the hydraulic resistance of a tube packed with sand, as reported by Leibenson, and the equations of the present authors, the following results were obtained: For the average effective diameter of particles of fine sand, the Leibenson formula gave 0.22 mm.; the Slichter curve, based on weight units, gave 0.223. A similar value of $d_{\rm ef}$ (0.225) can be directly found if the average diameter of particles of the predominating fraction of the sand layer (over 50 per cent) is considered. The relative porosity of the sand determined from specific gravity is 2.5 times larger than the free space in the layer calculated from equation /12/, considering that $D_{\rm g}=d_{\rm ef}$. It should be noted especially that the equation /46/ given by Leibenson was verified only for streamline flow, inasmuch as the experiments of the State Institute of Lineral Fuels were performed at Reynolds number not exceeding 21 and the critical value of the Reynolds number was 50 - 60. Correlation of experimental values of the hydraulic resistance of a sand layer with the value calculated from equation /47/ gave:

Vo in m./sec.	рд	p ₂	△ p _{exper.,} kg./sq. in.	△ p according to /47/
0.279	11000	940	1.0 × 10 ⁴	0.8 × 10 ⁴
1.141	22180	1040	2.1×10^4	3.3 x 10 ⁴

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These data show that the formula /47/ is applicable also for evaluation of the hydraulic resistance of a column packed with a non-uniform catalyst.

In conclusion, it should be noted that instead of three experimentally determined values characterizing the catalyst material (number of granules, surface of the granules and free volume of the catalyst bed) which are required for calculations by the Zhavoronkov formula, the formula derived by the present authors requires only a single determination of the free volume of the catalyst bed (from the volume of water or fine sand filling that space). The factor characterizing the catalyst packing according to this formula, i.e., the average grain diameter, can be found from equation /12/.

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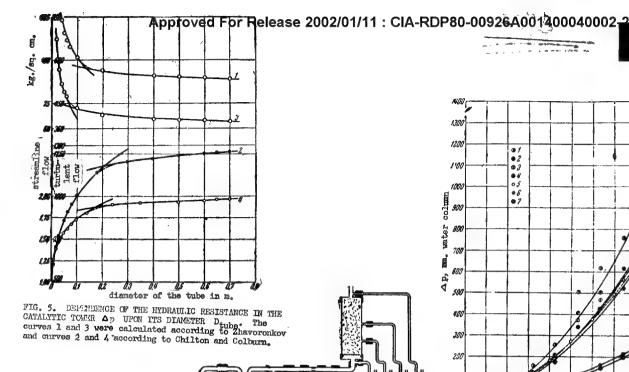
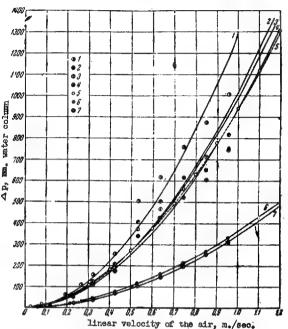


FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LIMEAR VELOCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST



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Linear velocity of the air, m./sec.

FIG. 7. DEPENDETCE OF THE HYDRAULIC RESISTANCE Δp OF COLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY
OF THE GAS STREAM OBSERVED IN THIS WORK. 1 - Δp at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; Δp at the exit from the column; 5 - Δp according to Δp ; Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn, assuming the average diameter of the particles to be equal to the cubic root of three dimensions.

3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT GOLUMN (D $_{\rm tube}$) ON THE VALUE OF K IN EQUATION P/46/

				to the decimal position of the same of the	Value of K in equation /46/			
No.	Flow	Interval of values of Dtube Dp		Interval of values (in m.) of Dtube for Dp = 0.0073 m.		from D _{tv} Extreme values D _{tube} given for the	be	
ı	turbulent	> 470	for D _{tube} = 0,7 M < 0,0015	> 3,43	3D p 0,085	interval (7; 4)	(2,64; 2,97) 1 tube 0.04	
2	N	470—77	0,0015-0,009	3,43-0,562	2,11 D _p 0,03	(3; 0,8)	(2,22; 2,12) $\frac{1}{D_{\text{tube}^0,04}}$	
3	*	77—25	0,009-0,0028	0,562-0,182	1,38 1 Dp 0,00	(0,5; 0,2)	$(1,35; 1,33) \frac{1}{L} = 0.04$	
4.	»	25—12	for 0,0028-0,0583	0,182-0,087	$1,16 \frac{1}{D_{\rm p}^{0,100}}$	(0,15; 0.09)	(1,05; 1,06) D _{tube 0,04}	
5	»	12-2,3	0,0033-0,017	0,087-0,017	3,08 D _p 0,202	(0,07; 0,018)	(3,2; 3,14) 1 tube 0.211	
6,	. »	<2,3	>0,017	< 0,017	17,62 D _p 0.620	(0,017; 0,003)	(8,5)* 1 cube 0.26 8	
1	streamline	>100	for D _{tube} = 0,07 m < 0,0073 (0,0005-0,0073)	> 0,73	51,38 D _p 0 13	(3; 0,9)	(51,9; 49) 1 tube 0,036	
2	,	< 100	> 0,0073 (0,0073-0,05)	< 0,73	$17,6 \frac{1}{D_{D} 0.098}$	(0,7; 0,06)	(16,6; 17,67) 1 tube 0.056	
3	. w	8—3	for D tube = 0,04 m 0,005-0,015	0,058-0,222	85,6 D p 0.873	(0,05; 0,02)	(85;89) 1 tube 0,81;	
4	*	3-1,2	0,015-0,034	0;022-0,0087	600 D _p 0.239	(0,03; 0,008)	(165,2) ⁴ 1 tube 0,428	
	• The numerical val	lue Approve	ed Egr Release, 200	2/01/11 CIA-	RDP80-00926A001	400040002-2 '	tube tube	

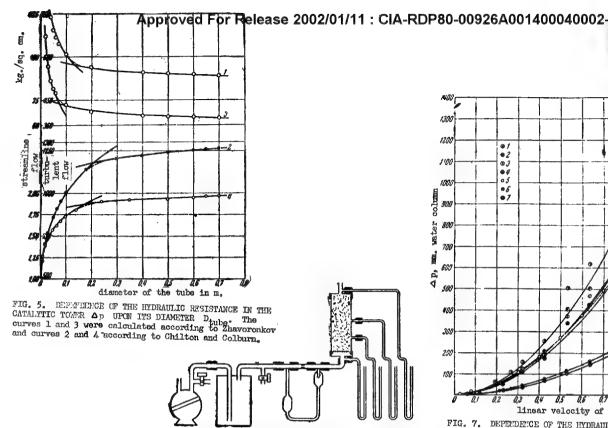


FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LINEAR VELOCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST

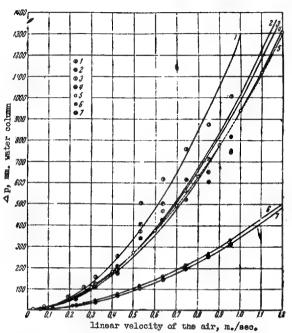


FIG. 7. DEPENDETCE OF THE HYDRAULIC RESISTANCE Δp OF TOLLINN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY. OF THE GAS STREAM OBSERVED IN THIS WORK. I - Δp at the air inlet to the column; $2 - \Delta p$ at the middle of the column; 3 - average values of Δp ; $4 - \Delta p$ at the exit from the column; $5 - \Delta p$ according to Zhavoronkov; $6 - \Delta p$ according to Chilton and Colburn; $7 - \Delta p$ according to Chilton and Colburn, assuming the average diameter of the particles to be equal to the cubic root of them. particles to be equal to the cubic root of three dimensions.

TABLE 3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT COLUMN (D_tube) ON THE VALUE OF K IN EQUATION $^p/46/$

		1	tuos, cu	1	1		
				* A STATE OF THE PARTY OF THE P	Value o	f K in equation /	46/
		Interval of values of	Interval of values of	Interval of values		from D	ibe
No.	Flow	D _{tube} /D _p	D for known D tube , m.	(in m.) of D _{tube} for D _p = 0.0073 m.	entire interval	Extreme values D _{tube} given for the interval	Values of K corresponding to them
1	turbulent	> 470	for D _{tube} = 0,7 M < 0,0015	> 3,43	3D p 0,085	(7; 4)	(2,64; 2,97) $\frac{1}{\Omega_{\text{tube}} 0.04}$
2	»	47077	0,0015-0,009	3,43-0,562	2,11 D _p 0,08	(3; 0,8)	$(2,22; 2,12) \frac{1}{D_{\text{tube}}0,04}$
3	*	77—25	0,009-0,0028	0,562-0,182	1,38 1 D.p 0,06	(0,5; 0,2)	$(1,35; 1,33) = \frac{1}{L_{-0.04}}$
4.	»	25-12	for 0,0028-0,0583 -Для Дер = 0,04 м	0,182-0,087	1,16 1 Dp 0,103	(0,15; 0.09)	(1,05; 1,06) 1 tube 0,04
5	»	12-2,3	0,0033-0,017	0,087-0,017	3,08 D p 0,202	(0,07; 0,018)	(3,2; 3,14) 1 1 1 tube 0,211
6,	»	<2,3	>0,017	< 0,017	17,62 D _p 0.629	(0,017; 0,003)	(8,5)* 1 cube ^{0.26 8}
1	streamline	>100	<pre>for D_{tube} = 0.07 m</pre>	> 0,73	51,38 D _p 0 12	(3; 0,8)	(51,9; 49) 1 tube 0,038
2	. %	< 100	> 0,0073 (0,0073-0,05)	< 0,73	17,6 1 D _p 0,098	(0,7; 0,06)	(16,6; 17,67) 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
3	»	8-3	for D tube = 0.01 M 0,005-0,015	0,058-0,222	85,6 D _p 0.878	(0,05; 0,02)	(85;89) 1 tube 0,81;
4	.	3-1,2	0,015-0,034	0,022-0,0087	600 D _p 0.839	(0,03; 0,008)	(165,2)* 1 tube: 0,428
	• The numerical va	In Approxe	doFor Release 200	2/Q1/161 _{1.16} CIA-F	RDP80-00926A0014	00040002-2	tube . " 42"

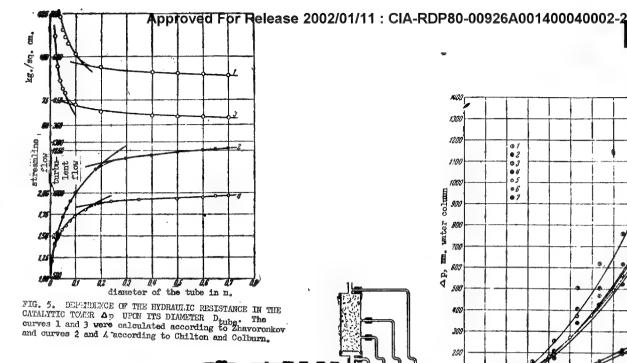


FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LINEAR VELCCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST

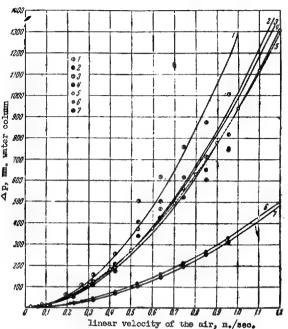


FIG. 7. DEPERDENCE OF THE INDRAULIC RESISTANCE Δp OF A COLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY OF THE GAS STREAM OBSERVED IN THIS WORK. 1 - Δp at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; 4 - Δp at the exit from the column; 5 - Δp according to Zhavoronkov; 6 - Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn, assuming the average diameter of the particles to be equal to the cubic root of three dimensions.

TABLE 3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT COLUMN (D $_{\rm tube}$) on the value of K in Equation $^{\rm p}/46/$

	1		0208	1	1		
	•				Value o	f K in equation /4	.6/
		Interval of values of	Interval of values of	Interval of values		from D	be
No.	Flow	D _{tube} /D _p	D _p for known D _{tube} , m.	(in m.) of D _{tube} for D _p = 0.0073 m.	entire interval	Extreme values D _{tube} given for the interval	Values of K corresponding to them
j	turbulent	> 470	for D _{tube} = 0,7 M	> 3,43	3D p 0,085	(7; 4)	(2,64; 2,97) $\frac{1}{\rho_{\text{tube 0,04}}}$
2	»	470-77	0,0015-0,009	3,43-0,562	2,11 D _p 0,03	(3; 0,8)	(2,22; 2,12) 1 Dtube 0,04
3	»	77—25	0,009-0,0028	0,562-0,182	1,38 1 D _{:p} 0,08	(0,5; 0,2)	$(1,35; 1,33) = \frac{1}{L_{-0}^{0.04}}$
4,	»	25-12	0,0028-0,0583	0,182-0,087	1,16 1 Dp 0,103	(0,15; 0.09)	(1,05; 1,06) 1 D _{tube} 0,04
5	»	12-2,3	0,0033-0,017	0,087—0,017	3,08 D p 0,202	(0,07; 0,018)	(3,2; 3,14) 1 1 tube 0,21;
6	»	<2,3	>0,017	< 0,017	17,62 D _p 0.629	(0,017; 0,003)	(8,5)* 1 cube 0.26 s
1	streamline	>100	for D _{tube} = 0,07 m < 0,0073 (0,0005-0,0073)	> 0,73	51,33 D _p 0 13	(3; 0,3)	(51,9; 49) 1 tube 0,056
2	. *	< 100	> 0,0073 (0,0073-0,05)	< 0,73	$17.6 \frac{1}{D_{p} 0.098}$	(0,7; 0,06)	(16,6; 17,67) 1 tube 0.056
3	No.	8-3	for D tube = 0,01 M 0,005-0,015	0,058-0,222	85,6 D _p 0.878	(0,05; 0,02)	(85;89) tube 0,313
4	*	3-1,2	0,015-0,034	0; 0 22-0,0087	600 D _p 0.839	(0,03; 0,008)	(165,2)* 1 tube 0,428
	• The numerical vo	ın Ap proxe	doFor Release 200	2/01/1 ₀₁₆ CIA-F	RDP80-00926A0014	00040002-2	tube . " """

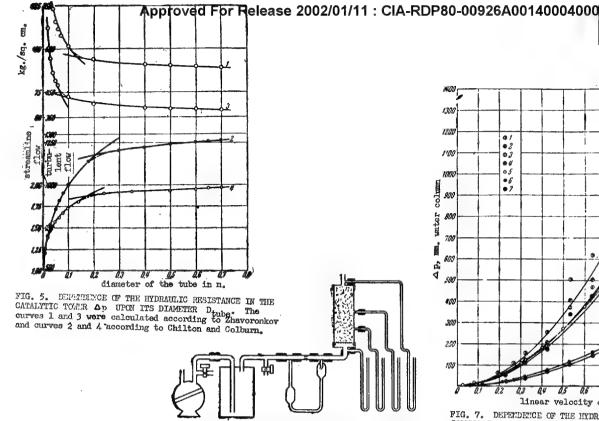
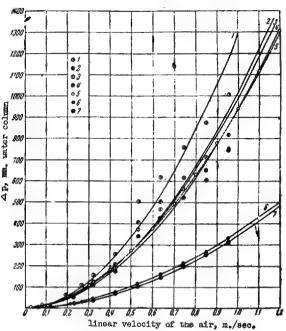


FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LINEAR VELOCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST



Ilnear velocity of the air, m./sec.

FIG. 7. DEPENDENCE OF THE HYDRAULIC RESISTANCE Δp OF ACCOLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY OF THE GAS STREAM OBSERVED IN THIS WORK. 1 - Δp at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; 4 - Δp at the exit from the column; 5 - Δp according to Δp ; 4 - Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn, assuming the average diameter of the particles to be equal to the cubic root of three dimensions.

TABLE 3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT COLUMN (D $_{\rm tube}$) ON THE VALUE OF K IN EQUATION $^{\rm p}/_{\rm 46}/$

]	·	tube,	1	1.		
					Value o	K in equation /	6/
:		Interval of values of	Interval of values of	Interval of values		from D _{th}	be
No.	Flow	D _{tube} /D _p	D _p for known D _{tube} , m.	(in m.) of D _{tube} for D _p = 0.0073 m.	entire interval	Extreme values D _{tubs} given for the interval	Values of K corresponding to them
1	turbulent	> 470	for D _{tube} = 0,7 M < 0,0015	> 3,43	3D p 0,065	(7; 4)	(2,64; 2,97) $\frac{1}{\rho_{\text{tube 0,04}}}$
2	»	470—77	0,0015-0,009	3,43-0,562	2,11 D _p 0,03	(3; 0,8)	(2,22; 2,12) 1 D _{tube} 0,04
3	»	7725	0,009—0,0028	0,562-0,182	1,38 1 D.p 0,06	(0,5; 0,2)	$(1,35; 1,33) = \frac{1}{L_{-0}^{0.04}}$
4.	»	25—12	6,0028-0,0583 for 0+052	0,182-0,087	1,16 1 D _p 0,103	(0,15; 0.09)	(1,05; 1,06) _D_tube 0,04
5	»	12-2,3	0,0033-0,017	0,087-0,017	3,08 D _p 0,202	(0,07; 0,018)	(3,2; 3,14) 1 tube 0,211
6	»	<2,3	>0,017	< 0,017	17,62 D _p 0.620	(0,017; 0,003)	(8,5)* 1 cube ^{0.26 8}
1	streamline	>100	for D _{tube} = 0.07 M < 0.0073 (0.0005-0.0073)	> 0,73	51,38 D _p 0 13	(3; 0,\$)	(51,9; 49) 1 tube 0,036
2	20	< 100	> 0,0073 (0,0073-0,05)	< 0,73	$17.6 \frac{1}{D_{\rm p} 0.098}$	(0,7; 0,06)	(16,6; 17,67), 1 tube 0,056
3	Xv	8-3	for D tube = 0,01 M 0,005-0,015	0,058-0,222	85,6 D 0.878	(0,05; 0,02)	(85,89) 1 tube 0,81;
4	*	3-1,2	0,015-0,034	0;0220,0087	600 D _p 0.839	(0,03; 0,008)	(165,2) ₀ * I tube 0,428
	* The numerical va	ın ∀labko xe	doFor Release 200	2/Q4/151 _{tube} CIA-F	RDP80-00926A0014	00040002-2	Tube Tube

FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LINEAR VELOCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST

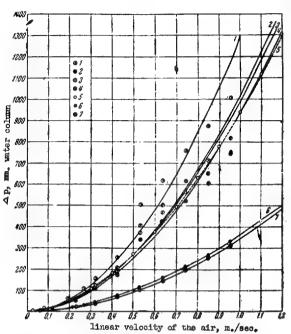


FIG. 7. DEPENDETCE OF THE HYDRAULIC RESISTANCE Δp OF A COLUMN WITH GRANULATED CATALAST UPON THE LINEAR VELOCITY. OF THE GAS STREAM OBSERVED IN THIS WORK. 1 - Δp at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; Δp at the exit from the column; 5 - Δp according to Δp according to Chilton and Column; 7 - Δp according to Chilton and Column; 7 - Δp according to Chilton and Column; assuming the average diameter of the particles to be equal to the cubic root of these particles to be equal to the cubic root of three dimensions.

Table 3. Effect of the average grain size of the catalyst (d) and the diameter of the contact column (p_{tube}) on the value of k in equation p/46/

					Value o	f K in equation /4	6/	
No.	Flow	Interval of values of Dtube Dp	values of	Interval of values of Dp for known Dtube, m.	Interval of values (in m.) of D _{tube} for D _p = 0.0073 m.	From D _p of the entire interval	from D _{tv} Extreme values D _{tube} given for the interval	Values of K corresponding to them
1	turbulent	> 470	for D _{tube} = 0,7 M < 0,0015	> 3,43	3D p 0,085	(7; 4)	(2,64; 2,97) 1 1 D _{tube} 0.04	
2	»	47077	0,0015-0,009	3,43-0,562	2,11 D _p 0,03	(3; 0,8)	(2,22; 2,12) 1 D _{tube} 0,04	
3	×	77—25	0,0090,0028	0,562-0,182	1,38 1 Dp 0,06	(0,5; 0,2)	(1,35; 1,33) $L_{-a^{0.04}}$	
4.	29	25-12	for 0,0028-0,0583 -Для Dry = 0,04 м	0,182-0,087	1,16 1 Dp 0,100	(0,15; 0.09)	(1,05; 1,06) _{D_{tube} 0,04}	
5	»	12-2,3	0,0033-0,017	0,087-0,017	3,08 D _p 0,202	(0,07; 0,018)	(3,2; 3,14) $\frac{1}{D_{\text{tube }}0,211}$	
6	<i>»</i>	<2,3	>0,017 for D _{tube} = 0,07 M	< 0,017	17,62 D _p 0,629	(0,017; 0,003)	(8,5)* 1 cube 0.26 s	
1	streamline	>100	(0,0073 (0,0005-0,0073)	> 0,73	51,38 D _p 0 12	(3; 0,8)	(51,9; 49) 1 tube 0,036	
2	* .	< 100	> 0,0073 (0,0073-0,05)	< 0,73	$17,6 \frac{1}{D_{\rm p}} \frac{1}{0.098}$	(0,7; 0,06)	(16,6; 17,67) 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
3	X 9	8-3	for D tube = 0,01 M 0,005-0,015	0,058-0,222	85,6 D _p 0.873	(0,05; 0,02)	(85;89) tube 0,81;	
4	*	3-1,2	0,615-0,034	0;022-0,0087	600 D _p 0.839	(0,03; 0,008)	(165,2)* 1 D tube 0,428	

The numerical valuapproved of or Release 2002/03/111 CIA-RDP80-00926A001400040002-2

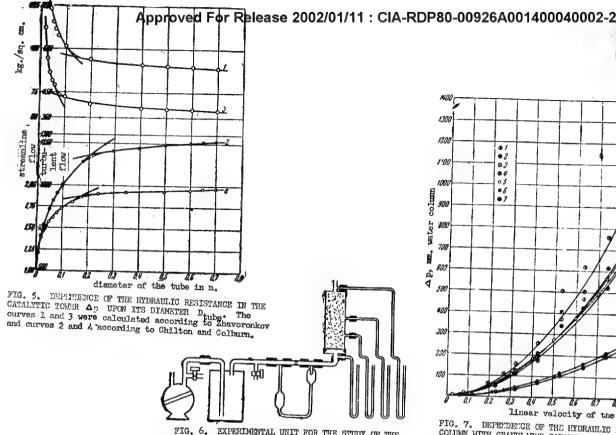
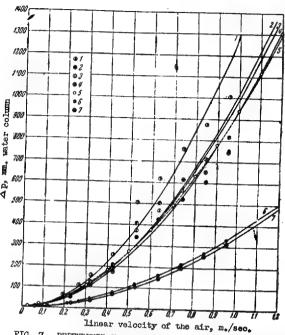


FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFICT OF THE LINEAR VELOCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST



Ilnear velocity of the air, m./sec.

FIG. 7. DEPERDENCE OF THE HYDRAULIC RESISTANCE Δp OF ACOLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY.

OF THE GAS STREAM OBSERVED IN THIS WORK. I - 4p at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; Δp at the exit from the column; 5 - Δp according to Zhavoronkov; 6 - Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn, assuming the average diameter of the particles to be equal to the cubic root of three

3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT COLUMN (D $_{\rm tube}$) ON THE VALUE OF K IN EQUATION P/46/

	(. ·	·	CONTACT COLUMN (Dtube) O	N THE VALUE OF K IN	EQUATION P/46/	EIER OF THE						
		-		· · · · · · · · · · · · · · · · · · ·	Value	of K in equation	/46/					
No.	Flow	Interval of values of Dtube p	Interval of values of D for known D tube , m	Interval of values (in m.) of Dtube for Dp = 0.0073 m.	From D of the entire interval	from D Extreme values Dtul given for the	tube					
1	turbulent	> 470	for D _{tube} = 0,7 m < 0,0015	> 3,43	3D p 0,085	(7; 4)	(2.64: 2.97)					
3	>>	470-77	0,0015-0,009	3,43-0,562	2,11 D p 0,03	(3; 0,8)	$(2,64; 2,97) \frac{1}{a_{\text{tube}}^{0.04}}$ $(2,22; 2,12) \frac{1}{a_{\text{tube}}^{0.04}}$					
4	3 9	77—25 25—12	0,009-0,0028	0,562-0,182	1,38 1 D.p. 0,06	(0,5; 0,2)	(1,35; 1,33) $\frac{1}{L_{-0}^{0.04}}$					
5	»	12-2,3	for 0.0028-0.0583	0,182-0,087	$1.16 \frac{1}{D_{\rm p} = 0.100}$	(0,15; 0.09)	(1,05; 1,06)					
6	»	<2,3	0,0033-0,017 >0,017	0,087-0,017	3,08 $D_{\rm p}$ 0,202	(0,07; 0,018)	(3,2; 3,14) 1 tube 0.211					
1	streamline	>100	for D _{tube} = 0.07 M	> 0,73	51,38 D _p 0.13	(0,017; 0,003)	(8,5)*					
2	>	< 100	$\begin{array}{c} (0,0005-0,0073) \\ > 0,0073 \\ (0,0073-0,05) \end{array}$	< 0,73	17,6 1 D 0,008		(51,9; 49) 1 tube 0,038					
3	20	8-3	for D tube = 0,04 m 0,005-0,015	0,058-0,222	D _p 0.004 85,6 D _p 0.873	(0,7; 0,06) (0,05; 0,02)	(16,6; 17,67)					
4	The numerice?	3-1,2	0,015-0,034	0;022-0,0087	600 /) 0.839	(0.00- 0.000)	(85,89) 1 tube 0,313					
		* The numerical value of Approved For Release 2062/01/11: CIA-RDP80-00926A001400040002-2 (165,2)* 1 tube 0,428										

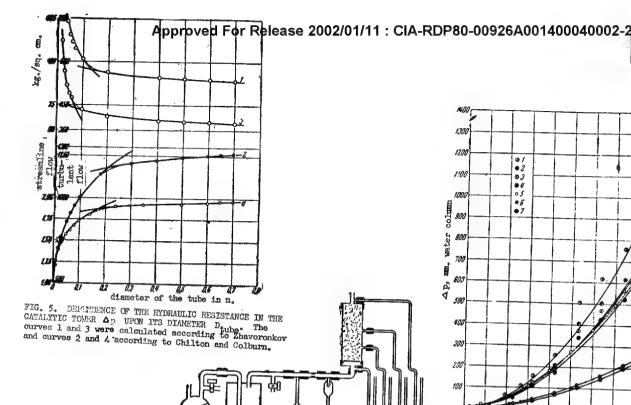
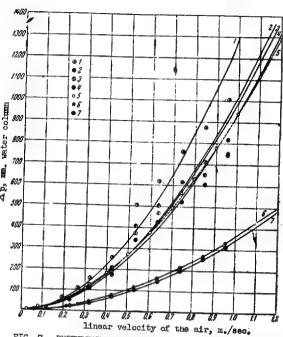


FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LINEAR VELOCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST



linear velocity of the air, m./sec.

FIG. 7. DEPETDENCE OF THE HYDRAULIC RESISTANCE Δp OF A COLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY OF THE GAS STREAM OBSERVED IN THIS WORK. 1 - 4p at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; 4 - Δp at the exit from the column; 5 - Δp according to Zhavoronkov; 6 - Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn, assuming the average diameter of the particles to be equal to the cubic root of three dimensions.

3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT COLUMN (D. ...) ON THE VALUE OF K IN FOLIATION P/A6/

	l	f	CONTACT COLUMN (Dtube) O	N THE VALUE OF K IN	RTALYST (D) AND THE DIAM FOUATION P/46/	ETER OF THE					
				e and a communication of a con-	Value	of K in equation	/46/				
No.	Flow	Interval of values of Dtube p	Interval of values of D for known D tube , T	Interval of values (in m.) of Dtube for	From D. of the	from D	The Real Property and the State of the State				
-) oute p	1	D _p = 0.0073 m.	entire interval	given for the interval	Values of K corresponding to them				
1	turbulent	> 470	for D _{tube} = 0,7 M < 0,0015	> 3,43	3D p 0,065	(7; 4)					
2	»	470—77	0,0015—0,009	3,43-0,562	2,11 D _p 0,03	(3; 0,8)	(2,64; 2,97) $\frac{1}{0_{\text{tube}} 0,04}$				
3	»	77—25	0,009-0,0028	0,562-0,182	1,38 1 D _{:p} 0,08	(0,5; 0,2)	(2,22; 2,12) 1 D _{tube} 0,04 (1,35; 1,33) 1				
4.	×	25-12	for 0,0028-0,0583	0,182-0,087	$1.16 \frac{D_{.p} 0.03}{D_{.p} 0.103}$	(0,15; 0.09)	$(1,35; 1,33) = \frac{1}{L_{-0}0.04}$				
5	»	12-2,3	0,0033-0,017	0,087-0,017	3,08 D _p 0,202	(0,07; 0,018)	(1,05; 1,06) <u>1</u> tube 0,04				
6	<i>»</i>	<2,3	>0,017	< 0,017	-		(3,2; 3,14) 1 D tube 0.211				
1	streamline	>100	for D _{tube} = 0.07 m		17,62 D _p 0,629	(0,017; 0,003)	(8,5)*1 cube 0.26 8				
			(0,0005-0,0073)	> 0,73	51,38 D _p 0 13	(3; 0,3)	(51,9; 49) 1 tube 0,056				
2	»	< 100	> 0,0073 (0,0073-0,05)	< 0,73	$17.6 \frac{1}{D_{p} 0.098}$	(0,7; 0,06)	(16,6; 17,67) 1/D _{tube} 0,056				
3	30	8-3	for D tube = 0,01 M 0,005-0,015	0,058-0,222	85,6 D _p 0.373	(0,05; 0,02)					
4		3-1,2	0,015-0,034	0; 0 22—0,0087	600 D 0,839	(0.02- 0.000)	(85;89) 1 tube 0,313				
Ì	* The numerical value of Approved-Fer Release 2002/01/11: CIA-RDP80-00926A001400040002-2 (165,2)* 1 tube 0,425										

FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LINEAR VELCCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH

SOLID GRANULATED CATALYST

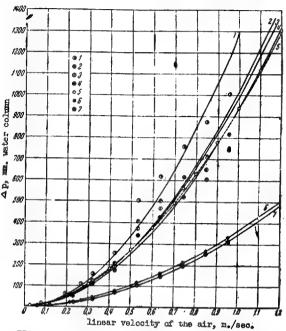


FIG. 7. DEPETDETCE OF THE HYDRAULIC RESISTANCE Δp OF COLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY OF THE GAS STREAM OBSERVED IN THIS WORK. 1 - Δp at the air inlet to the column; 2 - Δp at the middle of the column; 3 - Δp according to Δp , Δr - Δp at the exit from the column; 5 - Δp according to Zhavoronkov; 6 - Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn, assuming the average diameter of the particles to be equal to the oubic root of three dimensions.

TABLE 3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT COLUMN (D $_{\rm tube}$) ON THE VALUE OF K IN EQUATION $^{\rm P}/46/$

	La transfer of the second	· · · · ·	tube) on	I ANDOR OF W					
				The Property of the Property o	Value o	Value of K in equation /46/			
No.	777	Interval of values of	Interval of values of	Interval of values in m.) of Dtube for		from D	The		
	Flow	D _{tube} /D _p	D for known D tube , m.	$D_{\rm p} = 0.0073 \text{ m}.$	entire interval	Extreme values D _{tube} given for the interval	Values of K corresponding to them		
J	turbulent	> 470	for D _{tube} = 0.7 M < 0.0015	> 3,43	3 <i>D</i> _p 0,085	(7; 4)	(2,64; 2,97) 1 0 _{tube} 0,04		
2	»	47077	0,00150,009	3,43-0,562	2,11 D p 0,03	(3; 0,8)	(2,22; 2,12) $\frac{1}{D_{\text{tube}^{0,04}}}$		
3	*	77—25	0,009-0,0028	0,562-0,182	1,38 1 D.p 0,06	(0,5; 0,2)	$(1,35; 1,33) \frac{1}{L_{\odot} 0.04}$		
4	»	25-12	for 0,0028-0,0583	0,182-0,087	$1,16 \frac{1}{D_{p},0,100}$	(0,15; 0.09)	(1,05; 1,06)		
5	»	12-2,3	0,0083-0,017	0,087-0,017	3,08 D _p 0,202	(0,07; 0,018)	(3,2; 3,14) $\frac{1}{D_{\text{tube}} 0.211}$		
6,	<i>»</i>	<2,3	>0,017 for D _{tube} = 0.07 M	< 0,017	17,62 D _p 0.629	(0,017; 0,003)	(8,5)* 1 cube ^{0.26 8}		
	streamline	>100	(0,0005-0,0073)	> 0,73	51,38 D _p 0 13	(3; 0,9)	(51,9; 49) 1 tube 0,036		
2	»	< 100	> 0,0073 (0,0073-0,05)	< 0,73	17,6 1 0.008	(0,7; 0,06)	(16,6; 17,67), 1 tube 0,056		
3	,	8—3	for D tube = 0,01 M 0,005-0,015	0,058-0,222	85,6 D _p 0.373	(0,05; 0,02)	(85;89), 1 tube 0,31;		
4	•	3-1,2	0,015-0,034	0; 0 22—0,0087	600 D _p 0,839	(0,03; 0,008)	(165,2)* 1 tube 0,426		
	The numerical value Approved For Release 2002/01/61 CIA-RDP80-00926A001400040002-2								

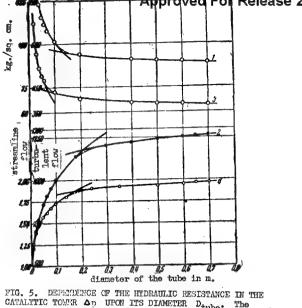


FIG. 5. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYTIC TOWER An UPON ITS DIAMETER Dubbe. The curves 1 and 3 were calculated according to Zhavoronkov and curves 2 and 4 according to Chilton and Colburn.

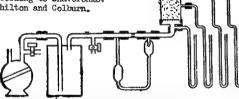


FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LINEAR VELOCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST

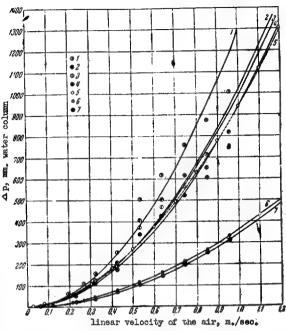
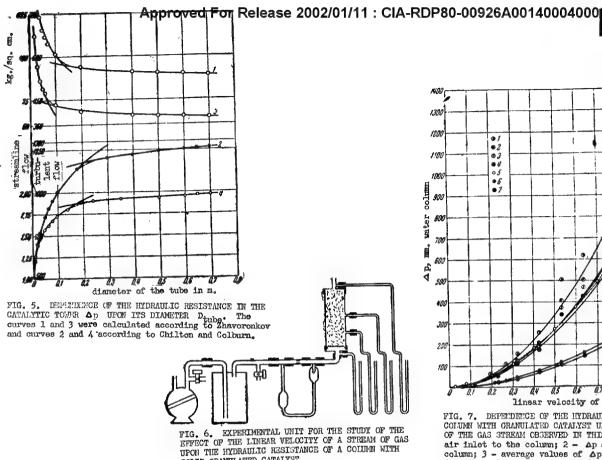


FIG. 7. DEPENDENCE OF THE HYDRAULIC RESISTANCE Δp OF A COLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY OF THE GAS STREAM OBSERVED IN THIS WORK. 1 - Δp at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; 4 - Δp at the exit from the column; 5 - Δp according to Zhavoronkov; 6 - Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn, assuming the average diameter of the particles to be equal to the cubic root of three dimensions.

TABLE 3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT COLUMN (D tube) ON THE VALUE OF K IN EQUATION $^{\rm p}/_{46}/$

1					Value o	f K in equation /4	6/
No.	Flow	Interval of values of Dtube Dp	Interval of values of D for known D tube , m.	Interval of values (in m.) of D _{tube} for D _p = 0.0073 m.		from D _{ta} Extreme values D _{tube} given for the interval	be
1	turbulent	> 470	for D _{tube} = 0,7 M < 0,0015	> 3,43	3D p 0,085	(7; 4)	(2,64; 2,97) $\frac{1}{0_{\text{tube}} 0.04}$
2	»	470—77	0,0015-0,009	3,43-0,562	2,11 D _p 0,03	(3; 0,8)	$(2,22; 2,12) \frac{1}{D_{\text{tube}}^{0,04}}$
3	*	77—25	0,009-0,0028	0,562-0,182	1,38 1 D.p 0,06	(0,5; 0,2)	$(1,35; 1,33) \frac{1}{L_{-0.04}}$
4.	»	2512	for 0,0028-0,0583 for 0 Tube 	0,182-0,087	1,16 1 Dp 0,103	(0,15; 0.09)	(1,05; 1,06) 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
5	»	12-2,3	0,0033-0,017	0,087-0,017	3,08 D _p 0,202	(0,07; 0,018)	(3,2; 3,14) $\frac{1}{D_{\text{tube }}0.211}$
6	»	<2,3	>0,017	< 0,017	17,62 D _p 0.629	(0,017; 0,003)	(8,5)* 1 cube ^{0,26 8}
1	streamline	>100	$\frac{\text{for } p_{\text{tube}} = 0.07 \text{ M}}{< 0.0073}$ $(0.0005 - 0.0073)$	> 0,73	51,33 D _p 0 13	(3; 0,9)	(51,9; 49) 1 tube 0,038
2	×	< 100	> 0,0073 (0,0073-0,05)	< 0,73	17,6 1 D _p 0.000	(0,7; 0,06)	(16,6; 17,67), 1 Tube ^{0,056}
3	SO .	8-3	for D _{tube} = 0,04 m 0,005-0,015	0,058-0,222	85,6 D _p 0.873	(0,05; 0,02)	(85,89) 1 tube 0,313
4		3-1,2	0,015-0,034	0; 0 22-0,0087	600 D _p 0.839	(0,03; 0,008)	(165,2)* 1 tube 0,428

The numerical value Approxed For Release, 2092/01/11 CIA-RDP80-00926A001400040002-2



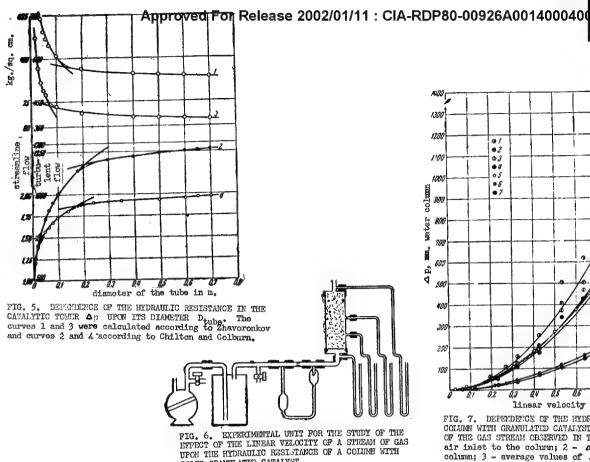
SOLID GRANULATED CATALYST

1300 1200 1100 1000 •6 900 water 700 į Δp, 300 200 100 115 linear velocity of the air, m./sec.

FIG. 7. DEPETDENCE OF THE HYDRAULIC RESISTANCE $\triangle p$ OF A COLUNN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY OF THE GAS STREAM OBSERVED IN THIS WORK. 1 - Ap at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; A - Δp at the exit from the column; 5 - Δp according to Zhavoronkov; 6 - Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn, assuming the average diameter of the perticles to be equal to the cubic root of three dimensions.

TABLE 3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT COLUMN (D_{tube}) ON THE VALUE OF K IN EQUATION P/46/

,	~	p	tube/ or	1103 111000 02 00		Thirty 15 Ask by Apple 1 year which marked drawler continue			
1	•				Value of	K in equation /4	THE REPORT OF THE PROPERTY OF THE PERSON NAMED IN THE PERSON NAMED IN THE PERSON NAMED IN THE PERSON NAMED IN		
		Interval of		Interval of values		from D	be		
No.	Flow	values of Dtube/Dp	Interval of values of D for known D tube , m.	(in m.) of Dtube for	From D of the entire interval	Extreme values D _{tube} given for the interval	Values of K corresponding to them		
1	turbulent	> 470	for D _{tube} = 0,7 M < 0,0015	> 3,43	3D p 0,085	(7; 4)	(2,64; 2,97) _{D_{tube} 0,04}		
2	»	470—77	0,00150,009	3,43-0,562	2,11 D _p 0,03	(3; 0,8)	(2,22; 2,12) 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		
3	»	77—25	0,009-0,0028	0,562-0,182	1,38 1 D.p 0,06	(0,5; 0,2)	$(1,35; 1,33) \frac{1}{L_{>0}^{-0.04}}$		
4.	29	25-12	For 0.0028-0.0583	0,182-0,087	1,16 $\frac{1}{D_p}$ 0,100	(0,15; 0.09)	(1,05; 1,06) 10 tube 0,04		
5	»	12-2,3	$\frac{D_{10} - D_{10}}{0.0033 - 0.017} = 0.04 \text{ M}$	0,087-0,017	3,08 D _p 0,202	(0,07; 0,018)	(3,2; 3,14) 1 tube 0,211		
6,	»	<2,3	>0,017	< 0,017	17,62 D _p 0,620	(0,017; 0,003)	(8,5)* 1 cube 0.28 8		
1	streamline	>100	$\frac{\text{for } p_{\text{tube}} = 0.07 \text{ m}}{< 0.0073}$ $(0.0005 - 0.0073)$	> 0,73	51,38 D _p 0 13	(3; 0,3)	(51,9; 49) 1 tube 0,038		
2	. »	< 100	> 0,0073 (0,0073-0,05)	< 0,73	17,6 1 0,088	(0,7; 0,06)	(16,6; 17,67) <u>1</u>		
3	3 0	8-3	for D _{tube} = 0,04 m 0,005-0,015	0,058-0,222	85,6 D _p 0.273	(0,05; 0,02)	(85;89) 1 tube 0,813		
4		3-1,2	0,015-0,034	0,022-0,0087	600 D _p 0,839	(0,03; 0,008)	(165,2) ₀ tube 0,428		
	* The numerical value pproved for Release 2002/01/11 CIA-RDP80-00926A001400040002-2								



SOLID GRANULATED CATALYST

.2 03 linear velocity of the air, m./sec.

FIG. 7. DEPENDENCE OF THE HYDRAULIC RESISTANCE Δp OF COLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY OF THE GAS STREAM OBSERVED IN THIS WORK. 1 - Δp at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; 4 - Δp at the exit from the column; 5 - Δp according to Zhavoronkov; 6 - Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn, assuming the average diameter of the particles to be expel to the cubic parts of these particles to be equal to the cubic root of three dimensions.

TABLE 3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT COLUMN (D $_{\rm tube}$) ON THE VALUE OF $\,k$ IN EQUATION $^{\rm p}/46/$

,	CONTACT COLUMN (D _{tube}) ON THE VALUE OF K IN EQUATION 7407									
	•				Value of K in equation /46/					
		Interval of		Interval of values		from D _{tube}				
No.	Flow	values of D _{tube} /D _p	Interval of values of D for known D tube; m.	in m.) of Dtube for	From D of the entire interval	Extreme values D _{tube} given for the interval	Values of K corresponding to them			
1	turbulent	> 470	for D _{tube} = 0,7 M < 0,0015	> 3,43	3D p 0,065	(7; 4)	(2,64; 2,97) <u>1</u>			
2	»	470-77	0,0015-0,009	3,43-0,562	2,11 D _p 0,08	(3; 0,8)	$(2,22; 2,12) \frac{1}{D_{\text{tube}}0,04}$			
3	»	77—25	0,0090,0028	0,562-0,182	1,38 1 D.p 0,06	(0,5; 0,2)	$(1,35; 1,33) \frac{1}{L_{2004}}$			
4.	»	25-12	0.0028-0.0583 10 Tube 10 Tube 10 Tube 10 Tube	0,182-0,087	1,16 1 D _p 0,100	(0,15; 0.09)	(1,05; 1,06) 10 tube 0,04			
5	»	12-2,3	0,0033-0,017	0,087-0,017	3,08 D p 0,202	(0,07; 0,018)	(3,2; 3,14) $\frac{1}{D_{\text{tube }}0.211}$			
6,	»	<2,3	>0,017	< 0,017	17,62 D _p 0,629	(0,017; 0,003)	(8,5)* 1 cube 0.26 8			
1	streamline	>100	$\frac{\text{for } p_{\text{tube}} = 0.07 \text{ m}}{< 0.0073}$ $< 0.0005 - 0.0073$	> 0,73	51,38 D _p 0 12	(3; 0,3)	(51,9; 49) 1 tube 0,056			
2	. •	< 100	> 0,0073 (0,0073-0,05)	< 0,73	$17,6 \frac{1}{D_{p}^{0.098}}$	(0,7; 0,06)	(16,6; 17,67) 1 tube 0,056			
3	ю	8-3	for D _{tube} = 0,01 m 0,005-0,015	0,058-0,222	85,6 D _p 0.373	(0,05; 0,02)	(85;89), 1 tube 0,81;			
4		3-1,2	0,015-0,034	0;022-0,0087	600 D _p 0.839	(0,03; 0,008)	(165,2)* 1 tube 0,428			
	* The numerical value Approyed For Release 2002/01/16 CIA-RDP80-00926A001400040002-2									

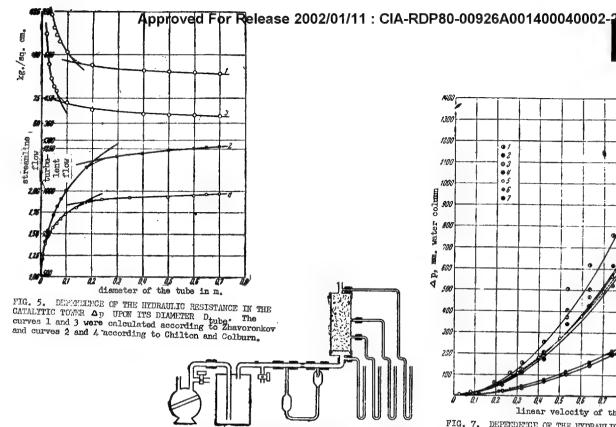


FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LINEAR VELOCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST

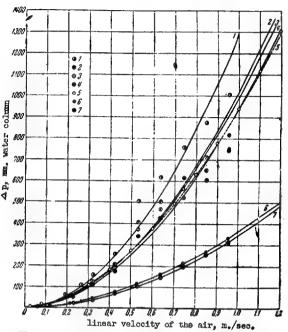


FIG. 7. DEPENDENCE OF THE HYDRAULIC RESISTANCE $\triangle p$ OF A COLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY OF THE GAS STREAM OBSERVED IN THIS WORK, 1 - Δp at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; 4 - Δp at the exit from the column; 5 - Δp according to Ehavoronkov; 6 - Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn, assuming the average diameter of the particles to be equal to the cubic most Δt three chiltons. particles to be equal to the cubic root of three dimensions.

TABLE 3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT COLUMN (D tube) ON THE VALUE OF K IN EQUATION P/46/

		4	GUO9'	.1	1.				
				The Proposition Specific States and St. C. C.	Value o	f K in equation /	46/		
No.	Flow	Interval of values of Dtube p	Interval of values of D for known D tube, m.	Interval of values (in m.) of Dtube for Dp = 0.0073 m.	From D of the entire interval	from Dtube Extreme values Dtube given for the interval	Values of K corresponding to them		
i	turbulent	> 470	for D _{tube} = 0,7 M < 0,0015	> 3,43	3D p 0,085	(7; 4)	(2,64; 2,97) 1 0 _{tube} 0,04		
2	»	470—77	0,0015—0,009	3,43-0,562	2.11 D _p 0,03	(3; 0,8)	(2,22; 2,12) 1 D _{tube} 0,04		
3	*	77—25	0,009-0,0028	0,562-0,182	1,38 -1 D.p 0,06	(0,5; 0,2)	$(1,35; 1,33) \frac{1}{L} = 0.04$		
4.	*	25-12	for 0,0028-0,0583	0,1820,087	1,16 Top 0,100	(0,15; 0.09)	(1,05; 1,06) 1 tube 0,04		
5	»	12-2,3	0,0033-0,017	0,087—0,017	3,08 D _p 0,202	(0,07; 0,018)	(3,2; 3,14) 1 tube 0,211		
6	<i>)</i> >	< 2,3	>0,017 for D _{tube} = 0,07 M	< 0,017	17,62 D _p 0.629	(0,017; 0,003)	(8,5)* 1 onbe 0.28 8		
	streamline	>100	<0,0073 (0,0005-0,0073)	> 0,73	51,38 D _p 0 13	(3; 0,8)	(51,9; 49) 1 tube 0,058		
2	. »	< 100	> 0,0073 (0,0073-0,05)	< 0,73	$17.6 \frac{1}{D_{\rm p} 0.098}$	(0,7; 0,06)	(16,6; 17,67). 10 tube 0,056		
3	»	83	$\frac{\text{for D}_{\text{tube}} = 0.01 \text{ M}}{0.005 - 0.015}$	0,058-0,222	85,6 D _p 0.873	(0,05; 0,02)	(85;89)		
4	*	3-1,2	0,015-0,034	0;022-0,0087	600 D _p 0,839	(0,03; 0,008)	(165,2)* 1 tube 0,428		
	The numerical value Approved, EpriRelease. 2002 LOM /4.1 CIA-RDP80-00926A001400040002-2								

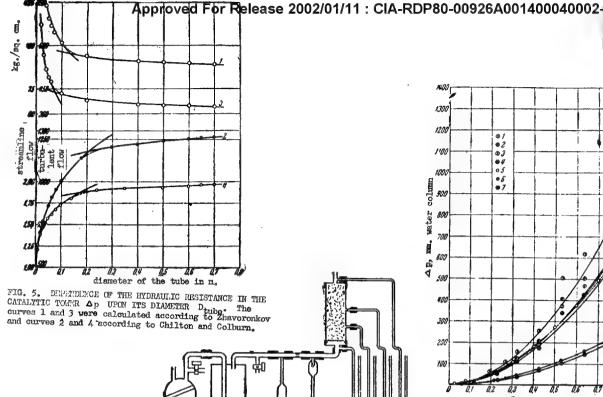


FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LINEAR VELOCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST

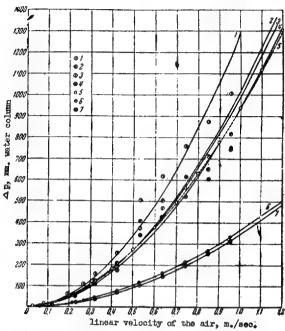


FIG. 7. DEPENDENCE OF THE HYDRAULIC RESISTANCE Δp OF COLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY OF THE GAS STREAM OSSERVED IN THIS WORK. 1 - 4p at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; $\Delta - \Delta p$ at the exit from the column; 5 - Δp according to Zhavoronkov; 6 - Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn; 3 - Δp according to Chilton and Colburn; 6 - Δp according to Chilton and Colburn, assuming the average diameter of the particles to be equal to the cubic root of three dimensions.

Table 3. Effect of the average grain size of the catalyst (D) and the diameter of the contact column (D $_{
m tube}$) on the value of K in equation $^{
m p}/_{46}/$

		Maria a sa s	1	to the same and and and and a	4					
			İ		Value of K in equation /46/					
		Interval of		Interval of values		from D _t	ha			
No.	Flow	values of Dtube Dp	Interval of values of Dp for known Dtube, m.	(in m.) of D _{tube} for D _p = 0.0073 m.	From D, of the entire interval	Extreme values D _{tubs} given for the interval	Values of K corresponding to them			
1	turbulent	> 470	for D _{tube} = 0,7 M < 0,0015	> 3,43	3D p 0,085	(7; 4)	(2,64; 2,97) 1 0 tube 0.04			
2	»	470—77	0,0015-0,009	3,43-0,562	2,11 D _p 0,03	(3; 0,8)	$(2,22; 2,12) \frac{1}{D_{\text{tube}^{0},04}}$			
3	æ	77—25	0,009-0,0028	0,562-0,182	1,38 1 D.p 0,06	(0,5; 0,2)	$(1,35; 1,33) \frac{1}{L_{-0}^{0,04}}$			
4.	×	25—12	for DTUBE -ARR DTD = 0.04 M	0,182-0,087	$1,16 \frac{1}{D_{p}^{0,109}}$	(0,15; 0.09)	$(1,05; 1,06) \frac{1}{D_{\text{tube }} 0.04}$			
5	»	12-2,3	0,0033-0,017	0,087-0,017	3,08 D p 0,202	(0,07; 0,018)	(3,2; 3,14) 1 tube 0,211			
6	»	< 2,3	>0,017 for D _{tube} = 0,07 M	< 0,017	17,62 D _p 0.629	(0,017; 0,003)	(8,5)* I cube ^{0.26 s}			
1	stroumline	>100	(0,0005-0,0073)	> 0,73	51,38 D _p 0 13	(3; 0,3)	(51,9; 49) 1 tube 0,056			
2	•	< 100	> 0,0073 (0,0073-0,05)	< 0,73	$17.6 \frac{1}{D_{p}^{0.098}}$	(0,7; 0,06)	(16,6; 17,67), 1 tube 0,056			
3	»	83	0,005-0,015	0,058-0,222	85,6 D p 0.273	(0,05; 0,02)	(85;89) 1 tube 0,813			
4	*	3-1,2	0,015-0,034	0;022-0,0087	600 D _p 0.839	(0,03; 0,008)	(165,2)* 1 tube 0,428			
	* The numerical value Approved Ear Release: 2062/Q1/11: CIA-RDP80-00926A001400040002-2									

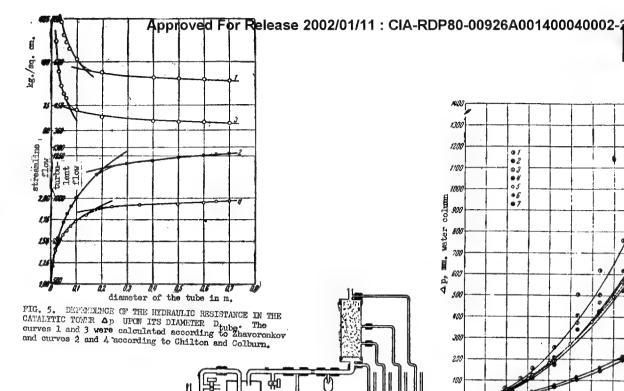


FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LINEAR VELOCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST

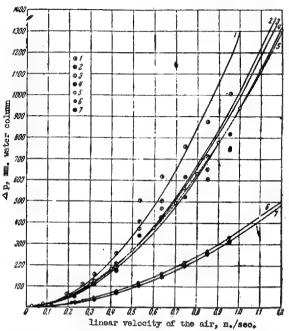


FIG. 7. DEPENDENCE OF THE HYDRAULIC RESISTANCE Δρ OF COLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY OF THE GAS STREAM OBSERVED IN THIS WORK. 1 - Δρ at the air inlet to the column; 2 - Δρ at the middle of the column; 3 - average values of Δρ; 4 - Δρ at the exit from the column; 5 - Δρ according to Zhavoronkov; 6 - Δρ according to Chilton and Colburn; 7 - Δρ according to Chilton and Colburn, assuming the average diameter of the particles to be equal to the middle root of three. particles to be equal to the cubic root of three dimensions.

Table 3. Effect of the average grain size of the catalyst (D) and the diameter of the contact column (D $_{\rm tube}$) on the value of $\,$ K in equation $^{\rm p}/_{\rm 46}/$

		į	tube on	THE VALUE OF A. IN	- FAURTION - / 40/		
					Value o	f K in equation /	46/
No.	Flow	Interval of values of Dtube Dp	Interval of values of D for known D tube, m.	Interval of values (in m.) of Dtube for Dp = 0.0073 m.	From D _p of the entire interval	from Dt. Extreme values Dtube given for the interval	Values of K corresponding to them
1	turbulent	> 470	for D _{tube} = 0,7 M < 0,0015	> 3,43	3D p 0,085	(7; 4)	(2,64; 2,97) 1 D _{table} 0,04
2	»	470-77	0,0015-0,009	3,43-0,562	2,11 D _p 0,08	(3; 0,8)	(2,22; 2,12) 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
3	»	77—25	0,009-0,0028	0,562-0,182	1,38 1 D.p 0,06	(0,5; 0,2)	$(1,35; 1,33) \frac{1}{L_{-6}^{0.04}}$
4.	29	25-12	For D Tube And Dry 0,0583	0,182-0,087	$1,16 \frac{1}{D_{\rm p},0,100}$	(0,15; 0.09)	(1,05; 1,06) 10 tube 0,04
5	»	12-2,3	0,0033-0,017	0,087-0,017	3,08 D _p 0,202	(0,07; 0,018)	(3,2; 3,14) 1 1 tube 0,211
6,	»	<2.3	>0,017	< 0,017	17,62 D _p 0.629	(0,017; 0,003)	(8,5)* 1 cube ^{0.26 8}
1	streamline	>100	for p _{tube} = 0.07 M < 0.0073 (0.0005-0.0073)	> 0,73	51,33 D _p 0 13	(3; 0,9)	(51,9; 49) 1 tube 0,036
2	· *	< 100	> 0,0073 (0,0073-0,05)	< 0,73	17,6 1 D _p 0,098	(0,7; 0,06)	(16,6; 17,67) 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
3	X)	8-3	for D tube = 0,04 M 0,005-0,015	0,058-0,222	85,6 D _p 0.873	(0,05; 0,02)	(85;89) 1 tube 0,313
4	*	3-1,2	0,015-0,034	0; 0 22-0,0087	600 D _p 0,839	(0,03; 0,008)	(165,2)* 1 tube 0,426
	• The numerical ve	lueApprove	ed Egr Release. 200	2/01/11 CIA-F	RDP80-00926A0014	100040002-2	tube tube

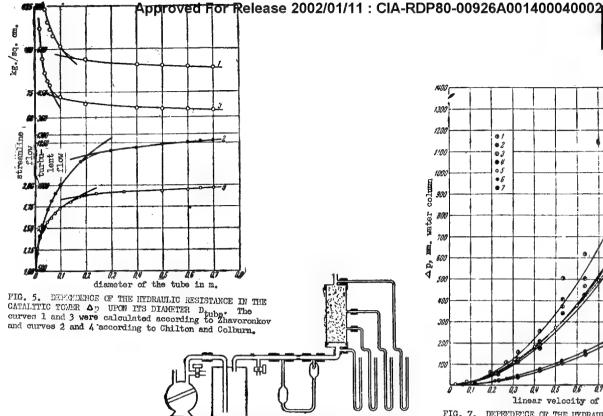


FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LINEAR VELOCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST

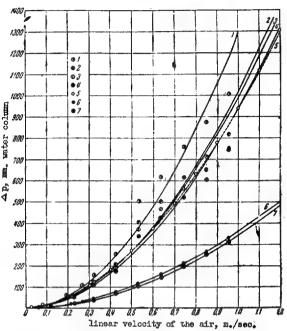


FIG. 7. DEPENDENCE OF THE HYDRAULIC RESISTANCE Δp OF COLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY OF THE GAS STREAM OBSERVED IN THIS WORK. 1 - Ap at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; 4 - Δp at the exit from the column; 5 - Δp according to Zhavoronkov; 6 - Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn; 8 - Δp according to Chilton and Colburn; 9 - Δp according to Chilton and Chi particles to be equal to the cubic root of three dimensions.

TABLE 3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT COLUMN (D_{tube}) ON THE VALUE OF $\,k\,$ IN EQUATION $^{\rm p}/46/$

		f	Luba		1		
	-				Value o	f K in equation /4	.6/
		Interval of		Interval of values		from D	ha
No.	Flow	values of tube p	Interval of values of D for known D tube, m.	An m lof De a for	From D of the entire interval	Extreme values D _{tube} given for the interval	Values of K corresponding to them
1	turbulent	> 470	for D _{tube} = 0.7 M < 0.0015	> 3,43	3D p 0,085	(7; 4)	(2,64; 2,97) 1 tube 0.04
2	»	470—77	0,0015-0,009	3,43-0,562	2,11 D _p 0,08	(3; 0,8)	(2,22; 2,12) $\frac{1}{p_{\text{tube}^{0,04}}}$
3	3 5	77—25	0,009-0,0028	0,562-0,182	1,38 1 D.p 0,06	(0,5; 0,2)	$(1,35; 1,33) \frac{1}{L_{-0}^{-0.04}}$
4.	26	25-12	for 0,0028—0,0583 — Для Dтуре — Для Dтуре 0,04 м	0,182-0,087	$1,16 \frac{1}{D_{\rm p}} \frac{1}{0,100}$	(0,15; 0.09)	(1,05; 1,06) 10 tube 0,04
5	»	12-2,3	0,0033-0,017	0,087-0,017	3,08 D _p 0,202	(0,07; 0,018)	(3,2; 3,14) 1 tube 0,211
6,	»	<2,3	>0,017	< 0,017	17,62 D _p 0.629	(0,017; 0,003)	(8,5)* 1 cube ^{0,28 8}
1	streamline	>100	$\frac{\text{for } n_{\text{tube}} = 0.07 \text{ M}}{< 0.0073}$ $< 0.0005 - 0.0073$	> 0,73	51,33 D _p 0 13	(3; 0,%)	(51,9; 49) tube 0,058
2		< 100	> 0,0073 (0,0073-0,05)	< 0,73	$17,6 \frac{1}{D_{\rm p}} \frac{1}{0.098}$	(0,7; 0,06)	(16,6; 17,67) 1 tube 0,056
3	u	8-3	for D tube = 0,01 M 0,005-0,015	0,058-0,222	85,6 D _p 0.273	(0,05; 0,02)	(85;89) 1 tube 0,31;
4	*	3-1,2	0,015-0,034	0; 0 22—0,0087	600 D _p 0.830	(0,03; 0,008)	(165,2) ^o 1 tube 0,428
	• The numerical ve	ı.ıAppko⊮e	d⊳Eor Release 200	2/Q1/1ե1 _{ւմ} ,CIA-F	RDP80-00926A0014	400040002-2	- CUDA

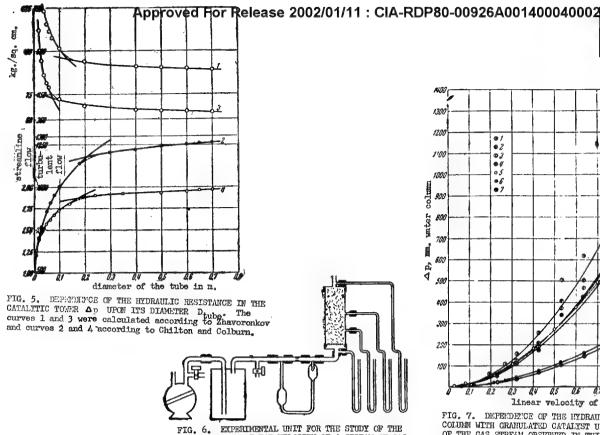


FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LINEAR VELOCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST

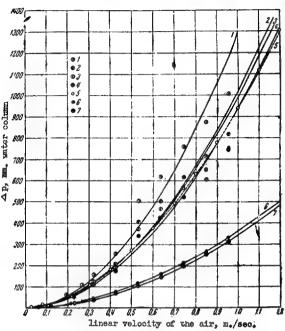


FIG. 7. DEPENDETCE OF THE HYDRAULIC RESISTANCE Δp OF A COLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY OF THE GAS STREAM OBSERVED IN THIS WORK. 1 - Δp at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; 4 - Δp at the exit from the column; 5 - Δp according to Zhavoronkov; 6 - Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn, assuming the average diameter of the particles to be squal to the cubic root of three particles to be equal to the cubic root of three dimensions.

TABLE 3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT COLUMN (D $_{tube}$) on the value of K in Equation P/46/

i		.	l cape,				
					Value o	f K in equation /4	6/
No.	Flow	Interval of values of Dtube Dp	Interval of values of Dp for known Dtube, m.	Interval of values in m.) of Dtube for Dp = 0.0073 m.	From D of the entire Interval	from D two Extreme values D tubs given for the interval	be Values of K corresponding to them
1	turbulent	> 470	for D _{tube} = 0,7 M < 0,0015	> 3,43	3D p 0,085	(7; 4)	(2,64; 2,97) $\frac{1}{\Omega_{\text{tube 0.04}}}$
2	»	470—77	0,0015-0,009	3,43-0,562	2,11 D _p 0,08	(3; 0,8)	(2,22; 2,12) $\frac{1}{D_{\text{tube}}^{0,04}}$
3	»	77—25	0,009-0,0028	0,562-0,182	1,38 1 D.p. 0,06	(0,5; 0,2)	$(1,35; 1,33) \frac{1}{L_{-0}^{0.04}}$
4.	ъ	25-12	for 0,0028—0,0583 — Для Пер 0,04 м	0,182-0,087	1,16 1 D _p 0,10a	(0,15; 0.09)	(1,05; 1,06) 10 tube 0,04
5	»	12-2,3	0,0033-0,017	0, 0 87—0,017	3,08 D p 0,202	(0,07; 0,018)	(3,2; 3,14) 1 1 1 tube 0.211
6	<i>»</i>	<2,3	>0,017	< 0,017	17,62 D _p 0,629	(0,017; 0,003)	(8,5)* 1 cube ^{0,26 8}
1	streamline	>100	for D _{tube} = 0.07 m < 0.0073 (0.0005-0.0073)	> 0,73	51,38 D _p 0 12	(3; 0,\$)	(51,9; 49) 1 tube 0,038
2	,	< 100	> 0,0073 (0,0073-0,05)	< 0,73	$17.6 \frac{1}{D_{p} 0.098}$	(0,7; 0,06)	(16,6; 17,67) <u>1</u>
3	Ų	8-3	$\frac{\text{for } D_{\text{tube}} = 0.04 \text{ m}}{0.005 - 0.015}$	0,058-0,222	85,6 D p 0.878	(0,05; 0,02)	(85;89) 1 tube 0,31;
4	3	3-1,2	0,015-0,034	0;022-0,0087	600 D _p 0,839	(0,03; 0,008)	(165,2) ⁴ 1 tube 0,428
	The numerical ve	Approve	differ Release 200	2/01/14 CIA-F	RDP80-00926A0014	100040002-2	- tupe

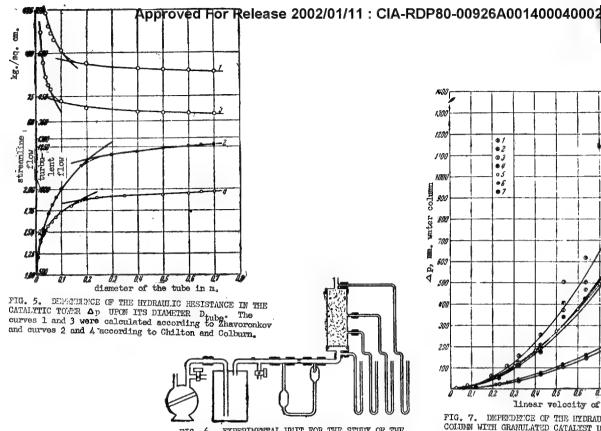


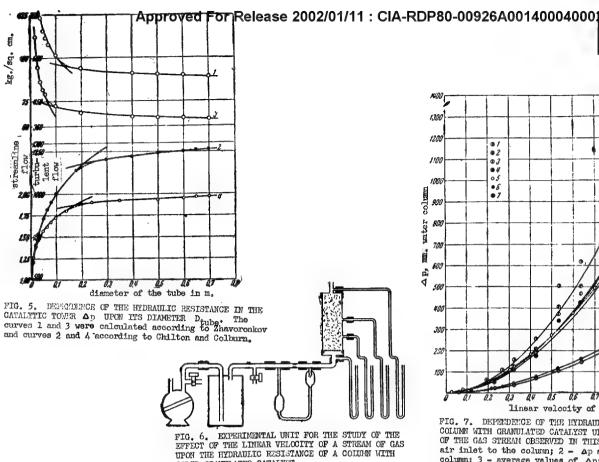
FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LINEAR VELCCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST

linear velocity of the air, m./sec.

FIG. 7. DEPENDETCE OF THE HYDRAULIC RESISTANCE Δp OF Δ COLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY. OF THE GAS STREAM OBSERVED IN THIS WORK. 1 - Δp at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; 4 - Δp at the exit from the column; 5 - Δp according to Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn, assuming the average diameter of the particles to be equal to the cubic root of three particles to be equal to the cubic root of three dimensions.

TABLE 3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT COLUMN (D tube) ON THE VALUE OF K IN EQUATION $^{\rm p}/_{46}$

		***************************************		· · · · · · · · · · · · · · · · · · ·	Value of	K in equation /4	.6/
No.	Flow	Interval of values of Dtube Dp	Interval of values of Dp for known Dtube , m.	Interval of values (in m.) of Dtube for Dp = 0.0073 m.		from D take Extreme values D tube given for the interval	be
1	turbulent	> 470	for D _{tube} = 0,7 m < 0,0015	> 3,43	3D p 0,085	(7; 4)	(2,64; 2,97) $\frac{1}{D_{\text{tube 0,04}}}$
2	»	470-77	0,0015—0,009	3,43-0,562	2,11 D _p 0,08	(3; 0,8)	(2,22; 2,12) $\frac{1}{D_{\text{tube}^{9,04}}}$
3	»	77—25	0,009-0,0028	0,562-0,182	1,38 1 Dp 0,06	(0,5; 0,2)	$(1,35; 1,33) \frac{1}{L = 0.04}$
4.	29	25-12	for D 70583 -And DTD = 0,04 M	0,182-0,087	1,16 10 0,100	(0,15; 0.09)	(1,05; 1,06) <u>1</u>
5	»	12-2,3	$\frac{-0.0033 - 0.017}{0.0033 - 0.017}$	0, 0 87—0,017	3,08 D p 0,202	(0,07; 0,018)	(3,2; 3,14) 1 tube 0,211
6,	»	<2.3	>0,017	< 0,017	17,62 D _p 0.629	(0,017; 0,003)	(8,5)* 1 cube 0.28 s
1	streamline	>100	$\frac{\text{for D}_{\text{tubs}} = 0.07 \text{ M}}{< 0.0073}$ $(0.0005 - 0.0073)$	> 0,73	51,38 D _p 0 12	(3; 0,9)	(51,9; 49) 1 tube 0,056
2	×	< 100	> 0,0073 (0,0073-0,03)	< 0,73	$17.6 \frac{1}{D_{p} 0.008}$	(0,7; 0,06)	(16,6; 17,67), 10 tube 0,056
3	×	8-3	$\frac{\text{for D}_{\text{tube}} = 0.01 \text{ m}}{0.005 - 0.015}$	0,058-0,222	85,6 D _p 0.873	(0,05; 0,02)	(85;89) 1 tube 0,31;
4	*	3-1,2	0,015-0,034	0; 0 22—0,0087	600 D _p 0.839	(0,03; 0,008)	(165,2) ⁴ 1
	• The numerical v	alu Approve	d Eor Release 200	2/01/11 tub CIA-F	RDP80-00926A0014	100040002-2	tube



SOLID GRANULATED CATALYST

1.300 1200 1100 03 •# 05 1000 • 6 900 700 500 300 200 100 linear velocity of the air, m./sec.

FIG. 7. DEPENDENCE OF THE HYDRAULIC RESISTANCE Δp OF A COLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY. OF THE GAS STREAM OBSERVED IN THIS WORK. 1 - Ap at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; 4 - Δp at the exit from the column; 5 - Δp according to Zhavoronkov; 6 - Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn, assuming the average diameter; of the particles to be equal to the cubic root of three particles to be equal to the cubic root of three dimensions.

Table 3. Effect of the average grain size of the catalyst (d) and the diameter of the contact column (D $_{
m tube}$) on the value of $_{
m K}$ in Equation $^{
m p}/_{46}/$

		p	tube) on	THE VALUE OF A IN	Monton /40/	- M	
					Value o	f K in equation /4	A ST THE COLUMN TWO IS NOT THE OWNER OF THE OWNER OWN
		Interval of		Interval of values		from D	be
No.	Flow	values of Dtube Dp	Interval of values of D for known D tube, m.	(in m.) of D _{tube} for bp = 0.0073 m.	From D of the entire interval	Extreme values D _{tubs} given for the interval	Values of K corresponding to them
1	turbulent	> 470	for D _{tube} = 0,7 M < 0,0015	> 3,43	3D p 0,085	(7; 4)	(2,64; 2,97) 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2	»	470—77	0,0015—0,009	3,43-0,562	2,11 D _p 0,03	(3; 0,8)	(2,22; 2,12) 1 Dtube 0,04
3	»	77—25	0,009-0,0028	0,562-0,182	1,38 1 D.p 0,08	(0,5; 0,2)	$(1,35; 1,33) \frac{1}{L_{-0}^{-0.04}}$
4.	>>	2512	for 0.0028-0.0583	0,182-0,087	1,16 1 D _p 0,103	(0,15; 0.09)	(1,05; 1,06) 1 Dtube 0,04
5	»	12-2,3	0,0033-0,017	0,087-0,017	3,08 D _p 0,202	(0,07; 0,018)	(3,2; 3,14) 1 tube 0,211
6,	»	<2,3	>0,017	< 0,017	17,62 D _p 0.629	(0,017; 0,003)	(8,5)* 1 cube ^{0.28 s}
1	streemline	>100	for D _{tube} = 0,07 m <0,0073 (0,0005-0,0073)	> 0,73	51,38 D _p 0 12	(3; 0,\$)	(51,9; 49) 1 tabe 0,056
2	. *	< 100	>.0,0073 (0,0073—0,03)	< 0,73	17,6 1 D _p 0,098	(0,7; 0,06)	(16,6; 17,67) 1 tube 0,056
3	X)	8-3	for D _{tube} = 0,04 m 0,005-0,015	0,058-0,222	85,6 D _p 0.873	(0,05; 0,02)	(85;89) 1 tube 0,31;
4	*	3-1,2	0,015-0,034	0;022-0,0087	600 D _p 0.839	(0,03; 0,008)	(165,2)* 1 tube 0,428
	• The numerical ve	lueApprov	ed Egr Release 200	2/Q1/11: CIA-	RDP80-00926A001	400040002-2	cuog

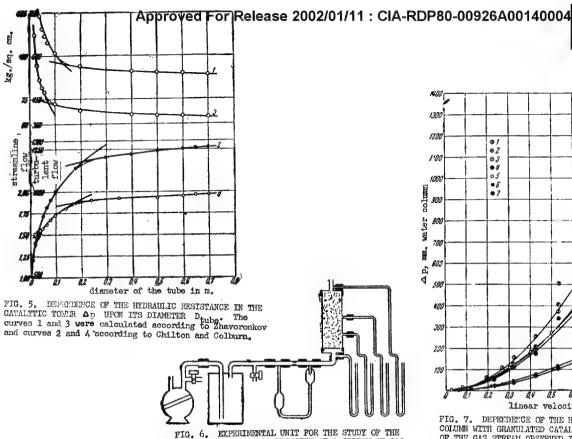


FIG. 6. EXPERIMENTAL UNIT FOR THE STUDY OF THE EFFECT OF THE LINEAR VELOCITY OF A STREAM OF GAS UPON THE HYDRAULIC RESISTANCE OF A COLUMN WITH SOLID GRANULATED CATALYST

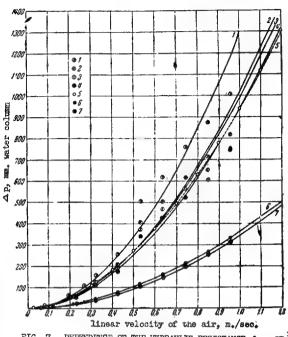


FIG. 7. DEPENDENCE OF THE HYDRAULIC RESISTANCE Δp OF COLUMN WITH GRANULATED CATALYST UPON THE LINEAR VELOCITY OF THE GAS STREAM OBSERVED IN THIS WORK. 1 - Δp at the air inlet to the column; 2 - Δp at the middle of the column; 3 - average values of Δp ; 4 - Δp at the exit from the column; 5 - Δp according to Zhavoronkov; 6 - Δp according to Chilton and Colburn; 7 - Δp according to Chilton and Colburn; 8 assuming the average diameter of the Particles to be expel to the cubic parts of the second of of the se particles to be equal to the cubic root of three dimensions.

TABLE 3. EFFECT OF THE AVERAGE GRAIN SIZE OF THE CATALYST (D) AND THE DIAMETER OF THE CONTACT COLUMN (D $_{\rm tube}$) on the value of $\,k\,$ in Equation $^{\rm P}\!/46/$

		F ****	t	1 · ·	1		
				The frageria space and the same	Value of	K in equation /4	6/
		Interval of values of		Interval of values		from D	be
No.	Flow	D _{tube} /D _p	Interval of values of D for known D tube, m.	(in m.) of D _{tube} for D _p = 0.0073 m.	From D of the entire interval	Extreme values Dtube given for the interval	Values of K corresponding to them
1	turbulent	> 470	for D _{tube} = 0,7 M < 0,0015	> 3,43	3D p 0,085	(7; 4)	(2,64; 2,97) $\frac{1}{\Omega_{\text{tube }}^{0},04}$
2	»	470-77	0,0015—0,009	3,43-0,562	2,11 D _p 0,03	(3; 0,8)	$(2,22; 2,12) \frac{1}{D_{\text{tube}}0,04}$
3	. **	77—25	0,009-0,0028	0,562-0,182	1,38 1 Dp 0,08	(0,5; 0,2)	$(1,35; 1,33) \frac{1}{L_{-0}^{0.04}}$
4.	25	25-12	For 0,0028-0,0583	0,182-0,087	1,16 1 Dp 0,103	(0,15; 0.09)	(1,05; 1,06) 1 tube 0,04
5	»	12-2,3	0,0033-0,017	0,087-0,017	3,08 D p 0,202	(0,07; 0,018)	(3,2; 3,14) $\frac{1}{D_{\text{tube}} 0.211}$
6,	»	<2,3	>0,017	< 0,017	17,62 D _p 0.629	(0,017; 0,003)	(8,5)* 1 cube 0.26 8
1	streamline	>100	$\frac{\text{for D}_{\text{tube}} = 0.07 \text{ M}}{<0.0005 - 0.0073}$	> 0,73	51,33 D _p 0 13	(3; 0,8)	(51,9; 49) 1 tube 0,056
2	. x	< 100	> 0,0073 (0,0073-0,05)	< 0,73	17,6 1 D 0,008	(0,7; 0,06)	(16,6; 17,67). 1 tube ^{0,056}
3	v	8-3	$\frac{\text{for D}_{\text{tube}} = 0.01 \text{ m}}{0.005 - 0.015}$	0,058-0,222	85,6 D _p 0.873	(0,05; 0,02)	(85;89) 1 tube 0,31;
4		3-1,2	0,015-0,034	0; 0 22—0,0087	600 D _p 0.839	(0,03; 0,008)	(165,2) ⁰ ₀ 1 tube 0,428
	• The numerical ve	elueApprovi	ed Figr Release 200	2/01/11 CIA-	RDP80-00926A001	400040002-2	- und

particles to be equal to the cubic root of three dimensions.

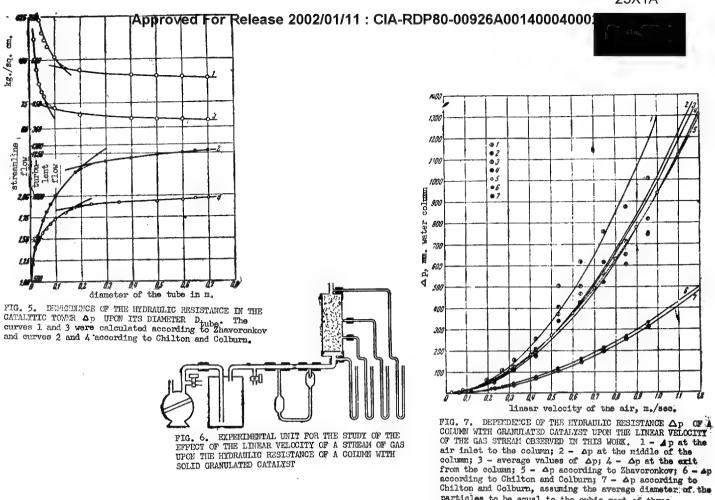
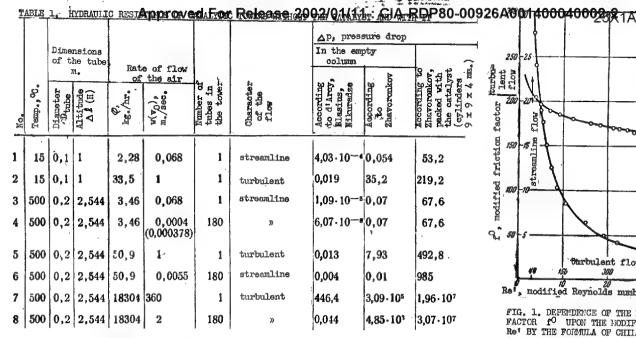


Table 3. Effect of the average grain size of the catalyst (D) and the diameter of the contact column (D $_{\rm tube}$) on the value of $\,$ K $\,$ IN Equation $^{\rm p}/46/$

1		p ====	tube) on	Ins vanos or a as	L		
					Value of	K in equation /4	6/
		Interval of		Interval of values		from D	he
No.	Flow	values of Dtube p	Interval of values of D _p for known D _{tube} , m.	in ma) of Danha for	From D of the entire interval	Extreme values D _{tube} given for the interval	Values of K corresponding to them
1	turbulent	> 470	for D _{tube} = 0,7 m < 0,0015	> 3,43	3D p 0,085	(7; 4)	(2,64; 2,97) <u>I</u>
2	»	470—77	0,0015-0,009	3,43-0,562	2,11 D _p 0,08	(3; 0,8)	$(2,22; 2,12) \frac{1}{D_{\text{tube}^{0},04}}$
3	×	77—25	0,009-0,0028	0,562-0,182	1,38 1 Dp 0,06	(0,5; 0,2)	$(1,35; 1,33) \frac{1}{L_{-6}^{0.04}}$
4.	»	25-12	0,0028-0,0583 F-7-4-0,04 M	0,182-0,087	1,16 1 D _p 0,103	(0,15; 0.09)	(1,05; 1,06) 1 tube 0,04
5	»	12-2,3	0,0033-0,017	0,087-0,017	3.08 D p 0,202	(0,07; 0,018)	(3,2; 3,14) $\frac{1}{D_{\text{tube }}0.211}$
6,	»	<2,3	>0,017	< 0,017	17,62 D _p 0.629	(0,017; 0,003)	(8,5)* 1 cube 0.26 s
1	streamline	>100	$\frac{\text{for D}_{\text{tube}} = 0.07 \text{ M}}{\langle 0.0073 \rangle}$	> 0,73	51,38 D _p 0 13	(3; 0,8)	(51,9; 49) 1 tube 0,058
2	, K	< 100	> 0,0073 (0,0073-0,05)	< 0,73	17,6 1 0,098	(0,7; 0,06)	(16,6; 17,67), 1 tube 0.056
3	ν	8-3	for D _{tube} = 0,04 m 0,005-0,015	0,058-0,222	85,6 D _p 0.373	(0,05; 0,02)	(85,89) 1 tube 0,313
4	*	3-1,2	0,015-0,034	0;022-0,0087	600 D _p 0.839	(0,03; 0,008)	(165,2)* 1 tube 0.428
	• The numerical va	Approve	d For Release 200	2/01/11/1 _{tub} CIA-F	RDP80-00926A0014	100040002-2	vuve



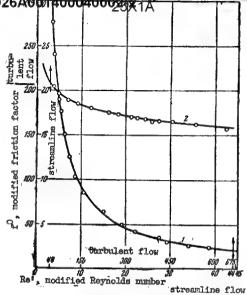


FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR f^O UPON THE HODIFIED REYMOLDS NUMBER Re'BY THE FORMULA OF CHILTON AND COLBURN. 1 - streamline flow; 2 - turbulent flow

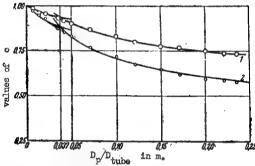


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS α UPON THE RATIO OF THE AVERAGE DIMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE DD/D by The FORMULA OF CHILTON AND COLBURN. D_p/D_{tube} 1 - for streamline flow; 2 - for turbulent flow

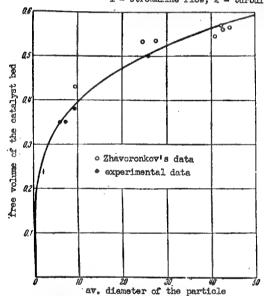


FIG. 3. DEPENDENCE OF THE FREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES.

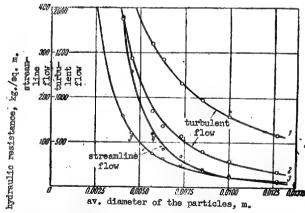
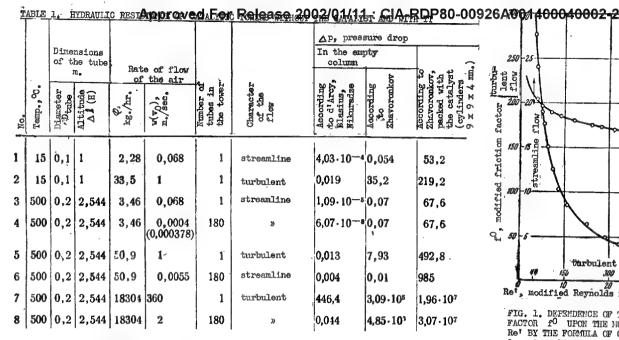


FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED Δp UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov. For streamline flow: 3 - according to Zhavoronkov; 4 - according to Chilton and Colburn.

TABLE 2. INTERDSPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE DIAMETER OF THE GRAIN

		DIAMETRIC OF THE	GRAIN		
No.	Type of packing	Shape	Dimensions of the grains, nm.	Av. diam- eter of the grain, mm.	Free space
1* 2* 3 4 5 6* 7	Glass rods Aluminosilicate catalyst Catalyst for con- version of CO Vanadium catalyst Coke Glass granules Coke	Cylinders Cylindrical tablets Tablets " Irregular Pear-shaped Irregular	$5 \times 5 \times 8$ $9 \times 9 \times 4$ $11 \times 11 \times 6$ $11 \times 11 \times 6.5$ $29.6 \times 25.8 \times 18$ $20 \times 20 \times 37.5$ $35.6 \times 28.8 \times 18$	6,0 7,3 9,3 9,5 24,5 25,8	0,35 0,35 0,38 0,43 0,532 0,500
8 9 10 11	Gravel Coke Andesite	Spherical Irregular	47,6×41,5×33,4 56,8×40,8×29 52×40,3×35,5 56×43,7×32,6	40,8 42,2 42,6 44,1	0,545 0,570 0,560 0,565



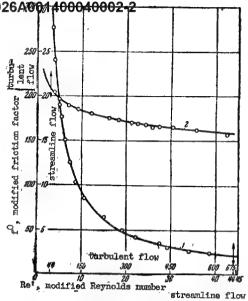


FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR f^0 UPON THE MODIFIED REYNOLDS NUMBER Re' BY THE FORMULA OF CHILTON AND COLBURN. 1 - streamline flow; 2 - turbulent flow

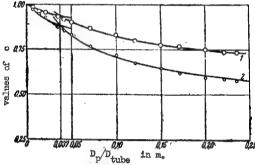


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS $\,$ UPON THE RATIO OF THE AVERAGE DIMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE $\,$ D_D/D_{tube} BY THE FORMULA OF CHILTON AND COLBURN. 1 - for streamline flow; 2 - for turbulent flow

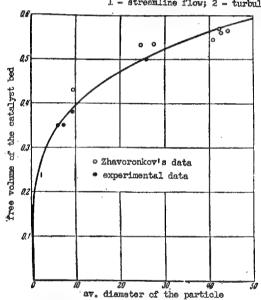
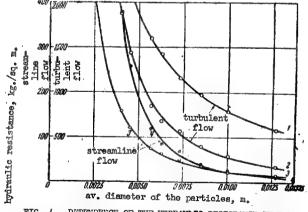


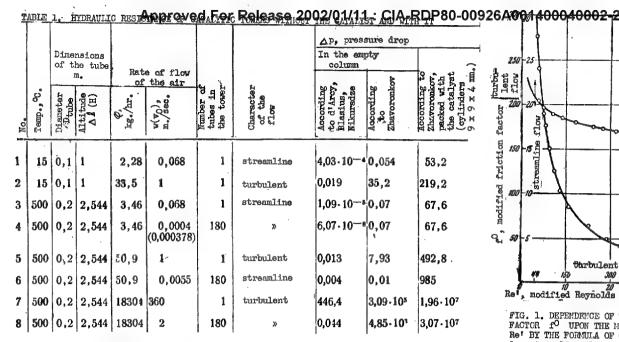
FIG. 3. DEPENDENCE OF THE FREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES.



DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED Ap UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov.
For streamline flow: 3 - according to Zhavoronkov; 4 according to Chilton and Colburn.

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE DIAMETER OF THE GRAIN

		JAMESTER OF THE	GRAIN		
No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diameter of the grain,	Free space
1* 2* 3 4 5 6*	dames grandes	Cylinders Cylindrical tablets Tablets " Irregular Pear-shaped	$5 \times 5 \times 8$ $9 \times 9 \times 4$ $11 \times 11 \times 6$ $11 \times 11 \times 6.5$ $29.6 \times 25.8 \times 18$ $20 \times 20 \times 37.5$	6,0 7,3 9,3 9,5 24,5 25,8	0,35 0,35 0,38 0,43 0,532 0,500
7 8 9 10 11	Coke "Gravel Coke Andesite	Irregular n Spherical Irregular	$\begin{array}{c} 35.6 \times 28.8 \times 18 \\ 47.6 \times 41.5 \times 33.4 \\ 56.8 \times 40.8 \times 29 \\ 52 \times 40.3 \times 35.5 \\ 56 \times 43.7 \times 32.6 \end{array}$	27,5 40,8 42,2 42,6 44,1	0,535 0,545 0,570 0,560 0,565



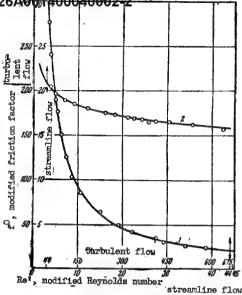


FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR ${\bf f^O}$ UPON THE MODIFIED REYNOLDS NUMBER Re' BY THE FORMULA OF CHILTON AND COLBURN. 1 - streamline flow; 2 - turbulent flow

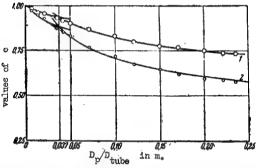


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS $\,$ UPON THE RATIO OF THE AVERAGE DIAMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE DY THE FORMULA OF CHILTON AND COLBURN. D_p/D_{tube} 1 - for streamline flow; 2 - for turbulent flow

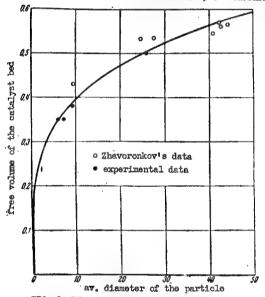


FIG. 3. DEPENDENCE OF THE FREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIAFETER OF THE PARTICLES.

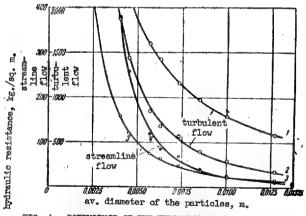
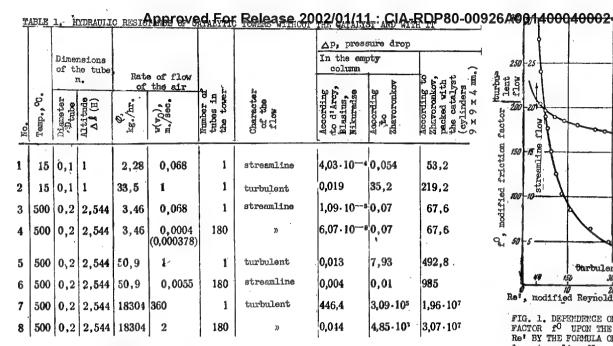


FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED Δ p UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov, 4 - according to Chilton and Colburn and Colburn.

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE DIAMETER OF THE GRAIN

		DIAMETER OF THE	GRAIN	-	
No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diam- eter of the grain, mm.	Free space
1* 2* 3 4 5 6*	Glass rods Aluminosilicate catalyst Catalyst for conversion of CO Vanadium catalyst Coke Glass granules Coke	Cylinders Cylindrical tablets Tablets " Irregular Pear-shaped Irregular	$5 \times 5 \times 8$ $9 \times 9 \times 4$ $11 \times 11 \times 6$ $11 \times 11 \times 6.5$ $29.6 \times 25.8 \times 18$ $20 \times 20 \times 37.5$ $35.6 \times 28.8 \times 18$	6,0 7,3 9,3 9,5 24,5 25,8 27,5	0,35 0,38 0,38 0,43 0,532 0,500
9 10 11	Gravel Coke Andesite	Spherical Irregular	47.6×41.5×33,4 56,8×40,8×29 52×40,3×35,5 56×43,7×32,6	40,8 42,2 42,6 44,1	0,545 0,570 0,560 0,565



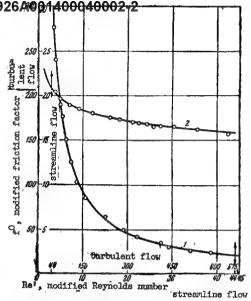


FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR f^O UPON THE MODIFIED REYNOLDS NUMBER Re' BY THE FORMULA OF CHILTON AND COLBURN. 1 - streamline flow; 2 - turbulent flow

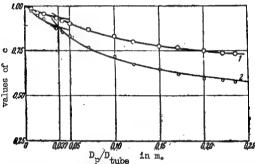


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS $\,$ C UPON THE RATIO OF THE AVERAGE DIAMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE $\,$ DD/D $\,$ BY THE FORMULA OF CHILTON AND COLBURN. D_p/D_{tube} 1 - for streamline flow; 2 - for turbulent flow

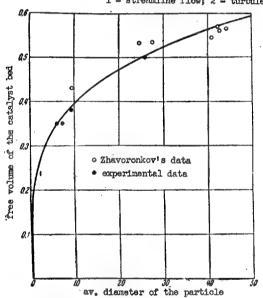


FIG. 3. DEPENDENCE OF THE FREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES.

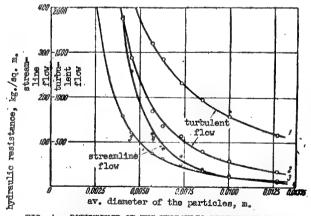
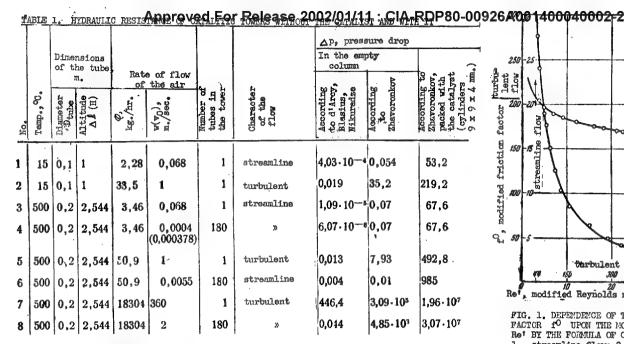


FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED Δ p UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov.
For streamline flow: 3 - according to Zhavoronkov; 4 - according to Chilton and Colburn.

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE DIAMETER OF THE CRAIM

No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diam- eter of the grain, mm.	Free space
1* 2* 3 4 5 6* 7 8 9	Aluminosilicate catalyst Catalyst for conversion of 00 Vanadium catalyst Coke Glass granules Coke " Gravel	Cylinders Cylindrical tablets Tablets " Irregular Pear-shaped Irregular Spherical	$5 \times 5 \times 8$ $9 \times 9 \times 4$ $11 \times 11 \times 6$ $11 \times 11 \times 6.5$ $29.6 \times 25.8 \times 18$ $20 \times 20 \times 37.5$ $35.6 \times 28.8 \times 18$ $47.6 \times 41.5 \times 33.4$ $56.8 \times 40.8 \times 29$	6,0 7,3 9,3 9,5 24,5 25,8 27,5 40,8 42,2	0,35 0,35 0,38 0,43 0,532 0,500 0,535 0,545 0,570
10 11	Coke Andesite	Irregular #	$52 \times 40,3 \times 35,5$ $56 \times 43,7 \times 32,6$	42,6 44,1	0,560 0,565



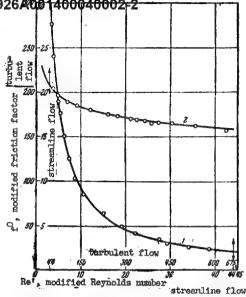


FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR f^O UPON THE MODIFIED REYNOLDS MUMBER Re'BY THE FORMULA OF CHILTON AND COLBURN. 1 - streamline flow; 2 - turbulent flow

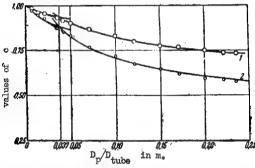


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS $\bf c$ UPON THE RATIO OF THE AVERAGE DIAMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE Dp/D bube BY THE FORMULA OF CHILTON AND COLBURN. 1 - for streamline flow; 2 - for turbulent flow

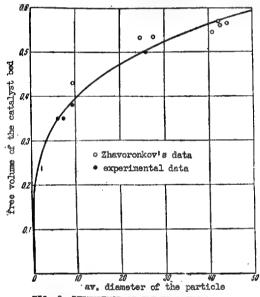


FIG. 3. DEPENDENCE OF THE FREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES.

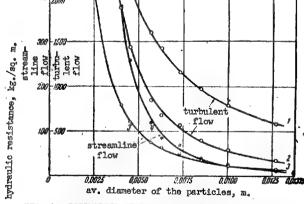
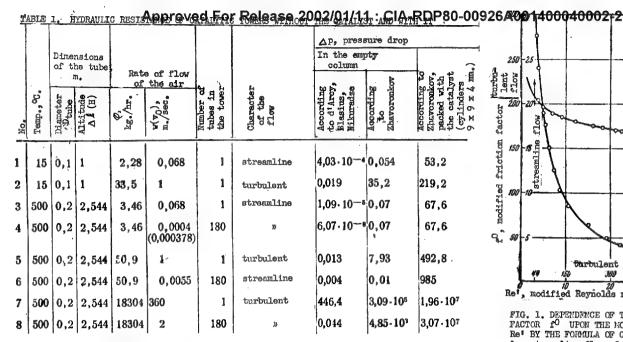


FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED Δ p UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov. For streamline flow: 3 - according to Zhavoronkov; 4 according to Chilton and Colburn,

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE DIAMETER OF THE CRAIN

No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diam- ster of the grain, mm.	Free space
1* 2* 3 4 5 6* 7 8 9 10 11	Glass rods Aluminosilicate catalyst Catalyst for conversion of CO Vanadium catalyst Coke Glass granules Coke " Gravel Coke Andesite	Cylinders Cylindrical tablets Tablets " Irregular Pear-shaped Irregular " Spherical Irregular	$5 \times 5 \times 8$ $9 \times 9 \times 4$ $11 \times 11 \times 6$ $11 \times 11 \times 6.5$ $29.6 \times 25.8 \times 18$ $20 \times 20 \times 37.5$ $35.6 \times 28.8 \times 18$ $47.6 \times 41.5 \times 33.4$ $56.8 \times 40.8 \times 29$ $52 \times 40.3 \times 35.5$ $56 \times 43.7 \times 32.6$	6,0 7,3 9,3 9,5 24,5 25,8 27,5 40,8 42,2 42,6 44,1	0,35 0,38 0,43 0,532 0,500 0,585 0,545 0,560 0,565



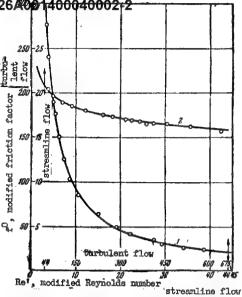


FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR f^O UPON THE MODIFIED REYNOLDS NUMBER Re $^{\rm 1}$ BY THE FORMULA OF CHILTON AND COLBURN. 1 - streamline flow; 2 - turbulent flow

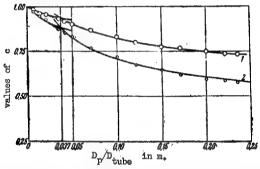


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS C UPON THE RATIO OF THE AVERAGE DI-AMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE D_{ν}/D_{ν} BY THE FORMULA OF CHILTON AND COLBURN. Dp/Dtube 1 - for streamline flow; 2 - for turbulent flow

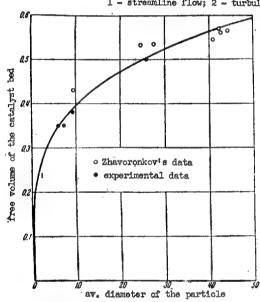


FIG. 3. DEPENDENCE OF THE FREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES.

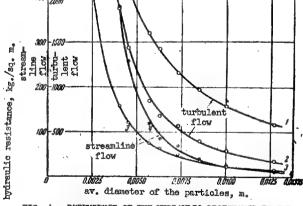


FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED Δ p UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov. For streamline flow: 3 - according to Zhavoronkov; 4 according to Chilton and Golburn.

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE

		DIAMETER OF THE	GRAIN		
No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diam- eter of the grain, mm.	Free space
1* 2* 3 4 5 6* 7 8 9 10	catalyst Catalyst for conversion of CO Vanadium catalyst Coke	Cylinders Cylindrical tablets Tablets " Irregular Pear-shaped Irregular Spherical Irregular	$5 \times 5 \times 8$ $9 \times 9 \times 4$ $11 \times 11 \times 6$ $11 \times 11 \times 6.5$ $29.6 \times 25.8 \times 18$ $20 \times 20 \times 37.5$ $35.6 \times 28.8 \times 18$ $47.6 \times 41.5 \times 33.4$ $56.8 \times 40.8 \times 29$ $52 \times 40.3 \times 35.5$ $56 \times 43.7 \times 32.6$	6,0 7,3 9,3 9,5 24,5 25,8 27,5 40,8 42,2 42,6 44,1	0,35 0,38 0,43 0,532 0,500 0,545 0,570 0,560 0,565

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T/	BLE :	L. Ĥ	YDRAULIO	RESIST	ANCE OF CA	TALYTIC	TOWERS WITHOUT	THE CATALYS	T AND WITH	IT
T								△p, press		
-	İ		sions e tube					In the emp	ty	~
•6	Temp., °C.	n	1.		of flow the air	Number of tubes in the tower	Juaracter of the flow	According to d'Arcy, Blasius, Nikuradze	According to Zhavoronkov	According to Zhavoronkov, packed with the catalyst (cylinders 9 x 9 x 4 mm.
<u>0</u>	H	A I	₩	<u> </u>			1	1		
1	15	0,1	1	2,28	0,068	1	streamline	4,03 - 10-4	0,054	53.2
2	15	0,1	1	33,5	1	1	turbulent	0,019	35,2	219,2
3	500	0,2	2,544	3,46	0,068	1	streamline	1,09-10-	0,07	67,6
4	500	0,2	2,544	3,46	0,0004 (0,000378)	180	»	6.07 · 10 - 8	0,07	67,6
5	500	0,2	2,544	50,9	1-	1	turbulent	0,013	7,93	492,8
6	500	0,2	2,544	50,9	0,0055	180	streamline	0,004	0,01	985
7	500	0,2	2,544	18304	360	1	turbulent	446,4	3,09 · 105	1,96 · 107
8	500	0,2	2,544	18304	2	180	»	0,044	4,85 · 103	3,07 - 107

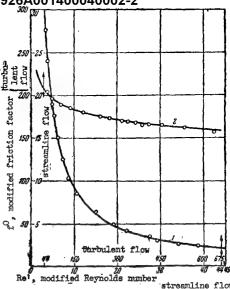


FIG. 1. DEPENDENCE OF THE MODIFIED FRIGTION FACTOR f⁰ UPON THE MODIFIED REMOULDS NUMBER Re* BY THE FORMULA OF CHILTON AND COLBURN. 1 - streamline flow; 2 - turbulent flow

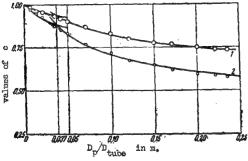


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS α UPON THE RATIO OF THE AVERAGE DIAMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE Dp/Dtube BY THE FORMULA OF CHILTON AND COLDURN. 1 - for streamline flow; 2 - for turbulent flow

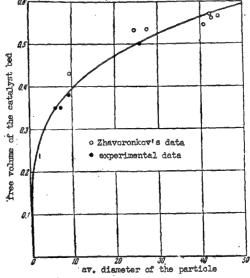


FIG. 3. DEPENDENCE OF THE FREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIALUTTER OF THE PARTICLES.

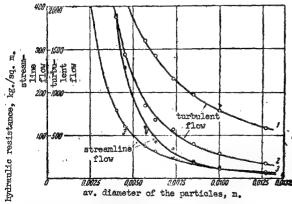


FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED $\Delta\, p$ UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 — according to Chilton and Colburn; 2 — according to Zhavoronkov. For streamline flow: 3 — according to Zhavoronkov; 4 — according to Chilton and Colburn.

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE DIAMETER OF THE GRAIN

No.	Type of packing	Shap e	Dimensions of the grains, mm.	Av. diam- eter of the grain,	Free space
1*	Glass rods	Cylinders	5×5×8	6,0	0.35
2*	Aluminosilicate	Cylindrical tablets	1	1	
3	catalyst Catalyst for con-	Tablets	$\begin{array}{c} 9 \times 9 \times 4 \\ 11 \times 11 \times 6 \end{array}$	7,3 9,3	0,35 0,38
4	version of CO Vanadium catalyst	16	11×11×6.5	9,5	0,43
5	Coke	Irregular	29,6×25,8×18	24,5	0,532
6*	Glass granules	Pear-shaped	$20 \times 20 \times 37.5$	25,8	0,500
7 8	Coke II	Irregular	$35,6 \times 28,8 \times 18$ $47,6 \times 41,5 \times 33,4$	27,5 40,8	0,535 0,545
9 10 11	Gravel Coke Andosite	Spherical Irregular #	56,8 × 40,8 × 29 52 × 40,3 × 35,3 56 × 43,7 × 32,6	42,2 42,6 44,1	0,570 0,560 0,565

Izv. (tekh.) 1946, 421 ff.

* Catalyst tested in this work

Approved For Release 2002/01/11 : CIA-RDP80-00926A001400040002-2 TABLE 1. HYDRAULIC RESISTANCE OF CATALYTIC TOWERS WITHOUT THE CATALYST AND WITH IT △p, pressure drop In the empty Dimensions 250 column of the tube Rate of flow Zhavoronkov, packed with the catalyst (cylinders m. Number of tubes in the tower Character of the flow According to d'Arcy, Blasius, Nikuradze 9 x 6 Zhavoronke Temp., C. ende E kg./hr. w(v), m./sec. 200 factor Ô friction 150 4,03 - 10 - 40,054 53,2 0,1 2,28 0,068 1 streamline 1 15 219,2 0,019 35,2 2 15 0.1 33,5 1 turbulent modified streamline 1,09-10-50,07 67,6 0,068 1 500 0.2 2.544 3,46 3 6,07.10-60,07 67,6 0,0004 180 2,544 3,46 500 0,2 ૡૢ૽૽ (0,000378)turbulent 0,013 7,93 492,8 5 500 0,2 2,544 50,9 1 turbulent flow streamline 0,004 0,01 985 0,0055 180 6 500 0.22,544 50.9 Re', modified Reynolds number turbulent 1,96 - 107 446,4 3,09 - 105 streamline flow 18304 360 1 7 500 0,2 2,544 FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR ${\bf f}^{O}$ UPON THE MODIFIED REYNOLDS MURBI 4,85-103 3,07 - 107 180 0,044 FACTOR fO UPON THE MODIFIED REYNOLDS NUMBER Re' BY THE FORMULA OF CHILTON AND COLBURN. 500 0,2 2,544 18304 1 - streamline flow; 2 - turbulent flow 0.1 0 0 0 07 성 8 catalyst 0.5 the $D_{\rm p}/D_{\rm tube}$ in m. **6**9 o Zhavoronkov's data FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS $\bf c$ UPON THE RATIO OF THE AVERAGE DIAMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE $\bf c$ by the Formula of Chilton and Colburn. volume experimental data Dp/Dtube 1 - for streamline flow; 2 - for turbulent flow 0. 300 av. diameter of the particle kg./sq. m. FIG. 3. DEPENDENCE OF THE FREE VOLUET: OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES. 200 TABLE 2. INTERDIPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE resistance, DIAMETER OF THE GRAIN turbulent flow Av. diameter of streamlin Dimensions of the the grain No. Type of packing flow Shape grains, mm. mm. hydraulic

av. diameter of the particles, m.
FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE
CATALYST BED Ap UPON THE AVERAGE DIAMETER OF THE
CATALYST GRAINS. For turbulent flow: 1 - according to
Chilton and Colburn; 2 - according to Zhavoronkov.
For streamline flow: 3 - according to Zhavoronkov: 4 -
according to Chilton and Colburn.

0,0050

0.0025

50ace Cylinders 1* Glass rods $5 \times 5 \times 8$ 6,0 0,35 2 Cylindrical Aliminosilicate $9\times9\times4$ $11\times11\times6$ tablets 0,35 catalyst 3 Catalyst for con-Tablets 9,3 0,38 version of CO $11 \times 11 \times 6.5$ 9,5 0,43 Vanadium catalyst Irregular Coke 0,532 0,500 $29,6 \times 25,8 \times 18$ 24,5 61 Pear-shaped $20 \times 20 \times 37,5$ 25,8 Glass granules Irregular Coke $35,6 \times 28,8 \times 18$ 27,5 $47,6 \times 41.5 \times 33,4$ $56,8 \times 40,8 \times 29$ $52 \times 40,3 \times 35,5$ $56 \times 43,7 \times 32,6$ 40,8 42,2 8 0,545 Gravel Spherical 0,570 Irregular 10 Coke 42,6 0.560 Andosite

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TA	BLE :	ı. İ	YDRAULIO	RESIST	CANCE OF CA	TALYTIC	TOWERS WITHOUT	THE CATALYS	T AND WITH	IT
T								Δp, press		
			nsions ne tube					In the emp	ty	, , ,
No.	Temp.,°C.		n.	of H		Number of tubes in the tower	Character of the flow	According to d'Arey, Blasius, Nikuredze	According to The The The The The The The The The The	According to Zhavoronkov, packed with the catalyst (cylinders 9 x 9 x 4 mm.
1	15	0,1	1	2,28	0,068	1	streamline	4,03 · 10-4	0,054	53,2
2	15	0,1	1	33,5	1	1	turbulent	0,019	35,2	219,2
3	500	0,2	2,544	3,46	0,068	1	streamline	1,09-10-5	0,07	67,6
4	500	0,2	2,544	3,46	0,0004 (0,000378)	180	»	6,07 · 10 - 8	0,07	67,6
5	500	0,2	2,544	50,9	1.	1	turbulent	0,013	7,93	492,8
6	500	0,2	2,544	50,9	0,0055	180	streamline	0,004	0,01	985
7	500	0,2	2,544	18304	360	1	turbulent	446,4	3,09 · 105	1,96 · 107
8	500	0,2	2,544	18304	2	180	»	0,044	4,85 · 103	3,07 - 107

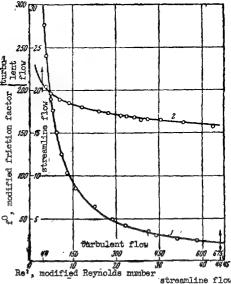


FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR fo UPON THE MODIFIED REYNOLDS NUMBER Re' BY THE FORMULA OF CHILTON AND COLBURN.

1 - streamline flow; 2 - turbulent flow

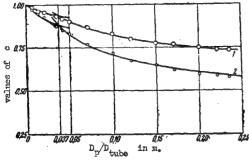


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS \circ UPON THE RATIO OF THE AVERAGE DIAMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE Dp/D bube BY THE FORMULA OF CHILTON AND COLBURN. 1 - for streamline flow; 2 - for turbulent flow

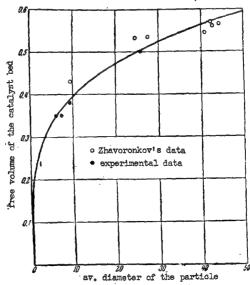


FIG. 3. DEPENDENCE OF THE FREE VOLUME: OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES.

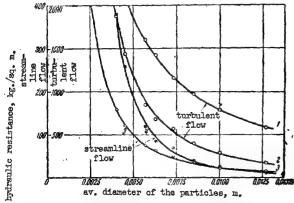


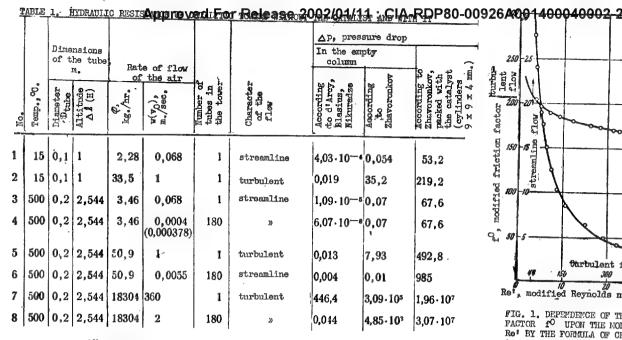
FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATAINST BED Δ p UPON THE AVERAGE DIAMETER OF THE CATAINST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov. For streamline flow: 3 - according to Zhavoronkov; 4 - according to Chilton and Colburn.

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE DIAMETER OF THE GRAIN

No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diam- eter of the grain, mm.	Free space
2* Alumica 3 Cata ve: Vana 5 Coke	el.	Cylinders Cylindrical tablets Tablets "Irregular Pear-shaped Irregular Spherical Irregular	$5 \times 5 \times 8$ $9 \times 9 \times 4$ $11 \times 11 \times 6$ $11 \times 11 \times 6.5$ $29.6 \times 25.8 \times 18$ $20 \times 20 \times 37.5$ $35.6 \times 28.8 \times 18$ $47.6 \times 41.5 \times 33.4$ $56.8 \times 40.8 \times 29$ $52 \times 40.3 \times 35.5$	6,0 7,3 9,3 9,5 24,5 25,8 27,5 40,8 42,2 42,6	0,35 0,38 0,43 0,532 0,500 0,535 0,545 0,570

Izv. (tekh.) 1946, 421 ff.

* Catalyst tested in this work



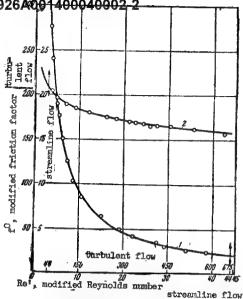


FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR f^O UPON THE MODIFIED REYNOLDS NUMBER Re'BY THE FORMULA OF CHILTON AND COLBURN. 1 - streamline flow; 2 - turbulent flow

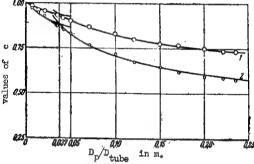


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS α UPON THE RATIO OF THE AVERAGE DIAMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE DD/D tube BY THE FORMULA OF CHILTON AND COLBURN. D_p/D_{tube} 1 - for streamline flow; 2 - for turbulent flow

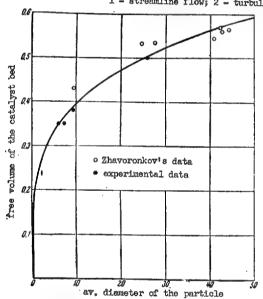


FIG. 3. DEPENDENCE OF THE FREE VOLUM: OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES.

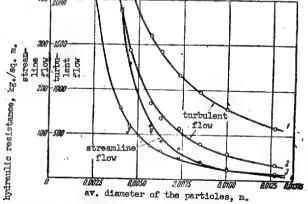
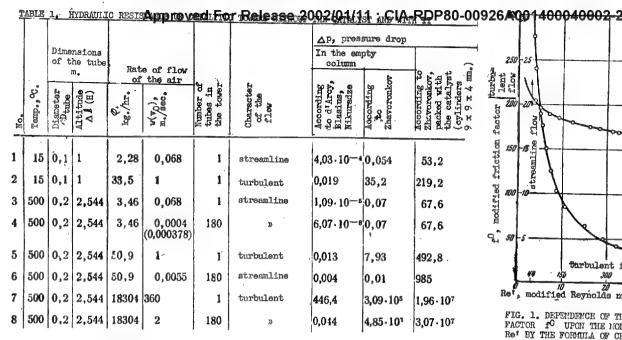


FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED Δ p UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov. For streamline flow: 3 - according to Zhavoronkov; 4 - according to Chilton and Colburn.

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE

No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diam- eter of the grain, mm.	Free space
2* Alum Cata Cata Vena Vana 5 Coke	əl	Cylinders Cylindrical tablets Tablets " Irregular Pear-shaped Irregular " Spherical Irregular	$5 \times 5 \times 8$ $9 \times 9 \times 4$ $11 \times 11 \times 6$ $11 \times 11 \times 6.5$ $29.6 \times 25.8 \times 18$ $20 \times 20 \times 37.5$ $35.6 \times 28.8 \times 18$ $47.6 \times 41.5 \times 33.4$ $56.8 \times 40.8 \times 29$ $52 \times 40.3 \times 35.5$ $56 \times 43.7 \times 32.6$	6,0 7,3 9,3 9,5 24,5 25,8 27,5 40,8 42,2 42,6 44,1	0,35 0,35 0,38 0,43 0,532 0,500 0,585 0,570 0,560



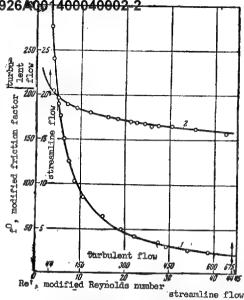


FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR f^O UPON THE MODIFIED REYNOLDS NUMBER Re' BY THE FORMULA OF CHILTON AND COLDURN. 1 - streamline flow; 2 - turbulent flow

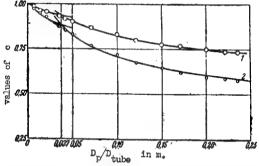


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE APERAGE DIOF THE WALLS C UPON THE RATIO OF THE AVERAGE DIAMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE
D_D_D_H_B
BY THE FORMULA OF CHILTON AND COLBURN. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT 1 - for streamline flow; 2 - for turbulent flow

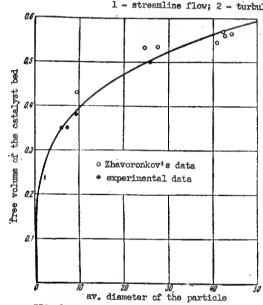
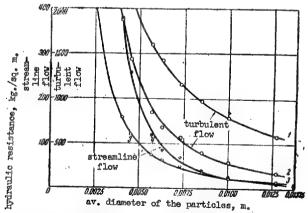


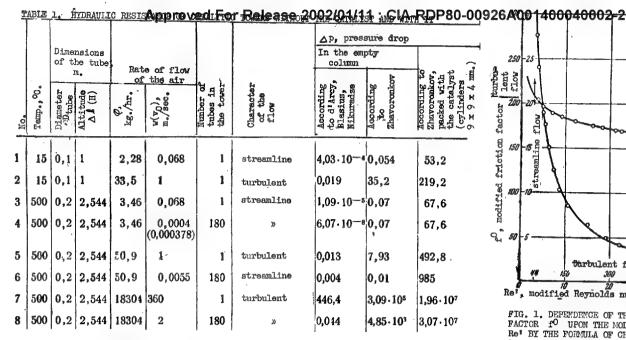
FIG. 3. DEPENDENCE OF THE FREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES.



DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED \triangle p UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Golburn; 2 - according to Zhavoronkov.
For streamline flow: 3 - according to Zhavoronkov; 4 according to Chilton and Colburn.

TABLE 2. INTERDSPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE

No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diam- eter of the grain, mm.	Free space
1* 2* 3 4 5 6* 7 8 9 10 11	Class rods Aluminosilicate catalyst Catalyst for conversion of CO Vanadium catalyst Coke Glass granules Coke Gravel Coke Andesite	Cylinders Cylindrical tablets Tablets " Irregular Pear-shaped Irregular " Spherical Irregular "	$5 \times 5 \times 8$ $9 \times 9 \times 4$ $11 \times 11 \times 6$ $11 \times 11 \times 6.5$ $29.6 \times 25.8 \times 18$ $20 \times 20 \times 37.5$ $35.6 \times 28.8 \times 18$ $47.6 \times 41.5 \times 33.4$ $56.8 \times 40.8 \times 29$ $52 \times 40.3 \times 35.5$ $56 \times 43.7 \times 32.6$	6,0 7,3 9,3 9,5 24,5 25,8 27,5 40,8 42,2 42,6 44,1	0,35 0,38 0,43 0,532 0,500 0,535 0,570 0,560 0,565



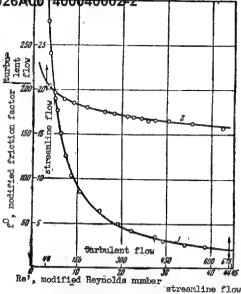


FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR f^O UPON THE MODIFIED REYNOLDS NUMBER Re' BY THE FORMULA OF CHILTON AND COLBURN. 1 - streamline flow; 2 - turbulent flow

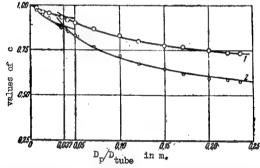


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS $\,^{\circ}$ UPON THE RATIO OF THE AVERAGE DIAMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE D, $/^{\circ}$ BY THE FORMULA OF CHILTON AND COLBURN. Dp/Dtube 1 - for streamline flow; 2 - for turbulent flow

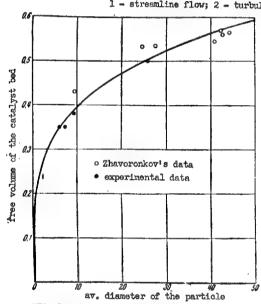
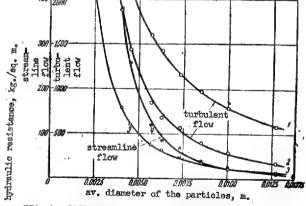


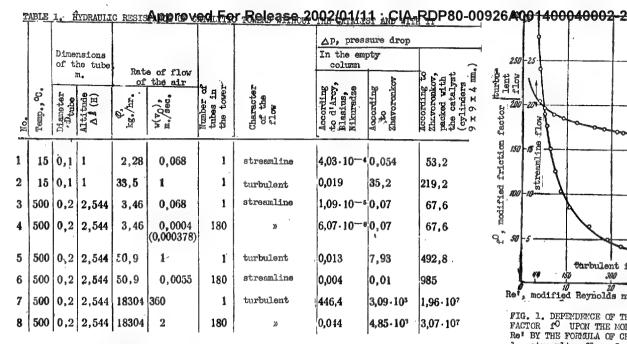
FIG. 3. DEPENDENCE OF THE FREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES.



DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE FIG. 4. DEFENDENCE OF THE HYDRAULTU RESISTANCE IN THE CATAINST BED Δ p UPON THE AVERAGE DIAMETER OF THE CATAINST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov. For streamline flow: 3 - according to Zhavoronkov; 4 - according according to Chilton and Colburn,

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE DIAMETER OF THE GRAIN

		DIAMETER OF THE	GRAIN		
No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diam- eter of the grain, mm.	Free space
1* 2* 3 4	Glass rods Aluminosilicate catalyst Catalyst for con- version of CO Vanadium catalyst	Cylinders Cylindrical tablets Tablets	5×5×8 9×9×4 11×11×6 11×11×6,5	6,0 7,3 9,3 9,5	0,35 0,35 0,38 0,43
5 6* 7 8	Coke Glass granules Coke	Irregular Pear-shaped Irregular	$ \begin{array}{c} 29.6 \times 25.8 \times 18 \\ 20 \times 20 \times 37.5 \end{array} $ $ \begin{array}{c} 35.6 \times 28.8 \times 18 \\ 20 \times 28.8 \times 18 \end{array} $	24,5 25,8 27,5	0,532 0,500 0,535
9 10 11	Gravel Coke Andesite	Spherical Irregular	47,6×41,5×33,4 56,8×40,8×29 52×40,3×35,5 56×43,7×32,6	40,8 42,2 42,6 44,1	0,545 0,570 0, 5 60 0,565



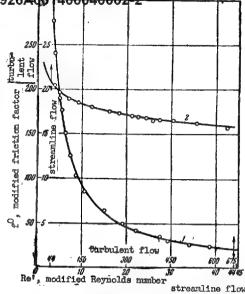


FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR fO UPON THE MODIFIED REYNOLDS MUMBER Re! BY THE FORMULA OF CHILTON AND COLBURN. 1 - streamline flow; 2 - turbulent flow

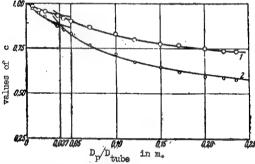


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS $\,$ UPON THE RATIO OF THE AVERAGE DIMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE $\,$ BY THE FORMULA OF CHILTON AND COLDURN. Dp/Dtube 1 - for streamline flow; 2 - for turbulent flow

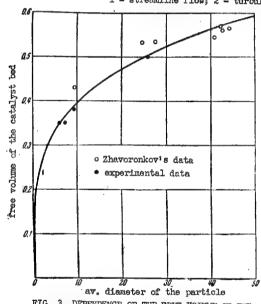
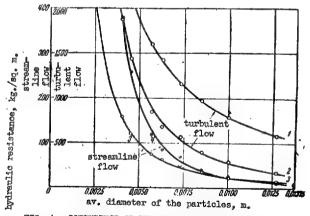


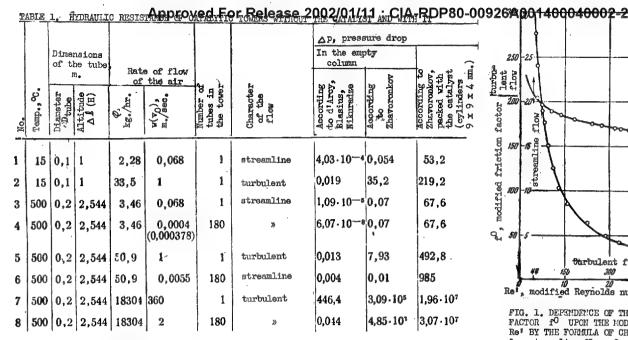
FIG. 3. DEPENDENCE OF THE FREE VOLUM: OF THE CATALYST BED UPON THE AVERAGE DIALETER OF THE PARTICLES.



DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED Δ p UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Golburn; 2 - according to Zhavoronkov.
For streamline flow: 3 - according to Zhavoronkov; 4 according to Chilton and Colburn.

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE DIAMETER OF THE GRAIN

No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diam- eter of the grain, mm.	Free space
1* 2* 3 4 5 6*	Glass rods Aluminosilicate catalyst Catalyst for con- version of CO Vanadium catalyst Coke Glass granules Coke	Cylinders Cylindrical tablets Tablets " Irregular Pear-shaped Irregular	$5 \times 5 \times 8$ $9 \times 9 \times 4$ $11 \times 11 \times 6$ $11 \times 11 \times 6.5$ $29.6 \times 25.8 \times 18$ $20 \times 20 \times 37.5$ $35.6 \times 28.8 \times 18$	6,0 7,3 9,3 9,5 24,5 25,8	0,35 0,36 0,38 0,43 0,532 0,500 0,535
8 9 10 11	Gravel Coke Andesite	Spherical Irregular	47,6×41,5×33,4 56,8×40,8×29 52×40,3×35,5 56×43,7×32,6	40,8 42,2 42,6 44,1	0,545 0,570 0, 5 60 0,565



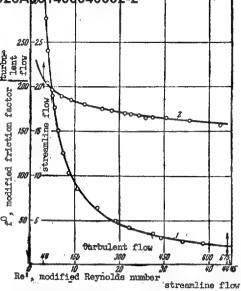


FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR f^O UPON THE MODIFIED REYNOLDS NUMBER Re'BY THE FORMULA OF CHILTON AND COLBURN. 1 - streamline flow; 2 - turbulent flow

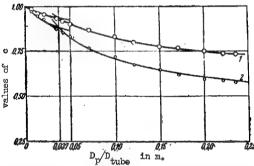


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS \circ UPON THE RATIO OF THE AVERAGE DIAMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE \circ Dy D_{tube} BY THE FORMULA OF CHILTON AND COLBURN. D_p/D_{tube} 1 - for streamline flow; 2 - for turbulent flow

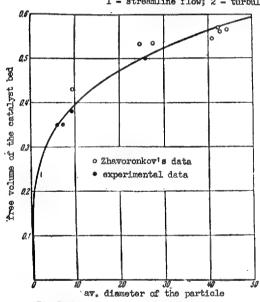


FIG. 3. DEPENDENCE OF THE FREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES.

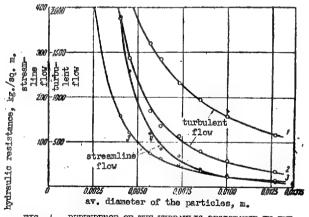
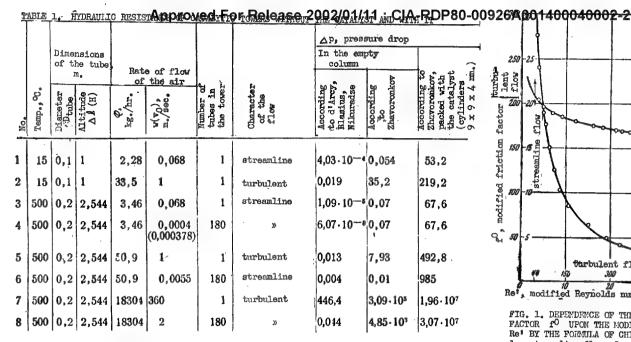


FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED Δ p UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov.
For streamline flow: 3 - according to Zhavoronkov; 4 - according to Chilton and Colburn.

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE

		DIAMETER OF THE	GRAIN	-	
No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diam- eter of the grain, mm.	Free space
2* 3	Glass rods Aluminosilicate catalyst Catalyst for con- version of CO Vanadium catalyst	Cylinders Cylindrical tablets Tablets	5×5×8 9×9×4 11×11×6 11×11×6,5	6,0 7,3 9,3 9,5	0,35 0,35 0,38
ŀ	Coke Glass granules	Irregular Pear—shaped	29,6×25,8×18 20×20×37,5	24,5 25,8	0,43 0,532 0,500
7 8 9 10 11	Coke Gravel Coke Andesite	Irregular " Spherical Irregular "	$\begin{array}{c} 35.6 \times 28.8 \times 18 \\ 47.6 \times 41.5 \times 33.4 \\ 56.8 \times 40.8 \times 29 \\ 52 \times 40.3 \times 35.5 \\ 56 \times 43.7 \times 32.6 \end{array}$	27,5 40,8 42,2 42,6 44,1	0,535 0,545 0,570 0,560 0,565

Izv. (tekh.) <u>1946</u>, 421 ff.



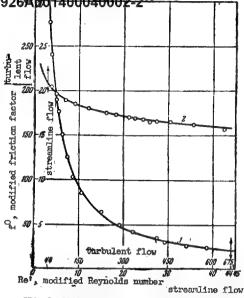


Fig. 1. DEFENDENCE OF THE MODIFIED FRIGTION FACTOR ${\bf f}^O$ UPON THE MODIFIED REYNOLDS NUMBER Re! BY THE FORMULA OF CHILTON AND COLBURN. 1 - streamline flow; 2 - turbulent flow

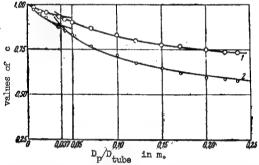


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS c UPON THE RATIO OF THE AVERAGE DIAMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE by the Formula of Chilton and Colburn. Dp/Dtube 1 - for streamline flow; 2 - for turbulent flow

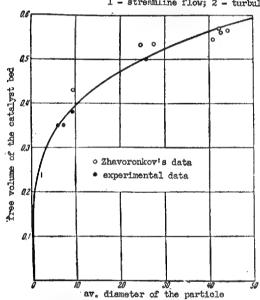
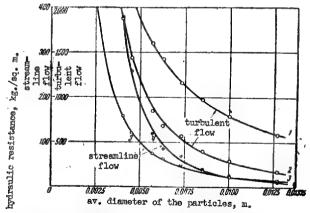


FIG. 3. DEPENDENCE OF THE PREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES.



DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED \$\Delta p\$ UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov.
For streamline flow: 3 - according to Zhavoronkov; 4 according to Chilton and Colburn.

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE

		DIAMETER OF THE	GRAIN		
No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diam- eter of the grain, mm.	Free space
1*	Glass rods	Cylinders			
2*	Aluminosilicate	Cylindrical	5×5×8	6,0	0,35
	catalyst	tablets	9×9×4	7,3	0.35
3	Catalyst for con-	Tablets	11×11×6	9,3	0,38
4	version of CO Vanadium catalyst	#	11×11×6,5	9,5	0,43
~	Coke	Irregular	$29.6 \times 25.8 \times 18$	24.5	Λ 59
6*	Glass granules	Pear-shaped	$20 \times 20 \times 37,5$	25,8	0,53 0,50
7	Coke	Irregular	$35.6 \times 28.8 \times 18$	27,5	0.53
8	" Cunme?	Fabruige?	$47,6 \times 41,5 \times 33,4$	40,8	0,54
10	Gravel Coke	Spherical Irregular	$56.8 \times 40.8 \times 29$	42,2	0,57
ii	Andesite	n	$52 \times 40.3 \times 35.5$ $56 \times 43.7 \times 32.6$	42,6 44,1	0,56 0,56

Approved For Release 2002/01/11: CIA-RDP80-00926A001400040002-2

11	BLE .	L. H	YDRAULI(RESIST	TANCE OF CA	TALYTIC	TOWERS WITHOUT	THE CATALYS	TIN DIA T	IT
								Δp, press	ure drop	
			nsions ne tube					In the emp	ty	~
			1.		of flow	مس ك	Ł		AO3	ng to mkov, with alyst era
]	ွင့်	15 g	(H)	ä	•°°	er of tower	Character of the flow	According to d'Arcy Blasius, Nikuradze	According To Zhavoronkov	According to Zhrvoronkov packed with the catalys (cylinders 9 x 4 m
No.	Temp.,	Diameter 'Dtube	Altitude A & (H)	kg./hr	E (V	Number tubes the to	Charac of th	According to d'Arey, Blasius, Nikuradze	Accol To Zhave	According 7 Zhrvoronkov pecked with the catalyx (cylinders 9 x 9 x 4 t
-	F- 1	H	-	<u>_</u>			<u> </u>	i	<u> </u>	1
1	15	0,1	1	2,28	0,068	1	streamline	4,03 - 10-4	0,054	53,2
2	15	0,1	1	33,5	1	1	turbulent	0,019	3 5,2	219,2
3	500	0,2	2,544	3,46	0,068	1	streamline	1,09-10-	0,07	67,6
4	500	0,2	2,544	3,46	0,0004 (0,000378)	180	»	6,07 · 10 - 8	0,07	67,6
5	500	0,2	2,544	50,9	1-	1	turbulent	0,013	7,93	492,8
6	500	0,2	2,544	50,9	0,0055	180	streamline	0,004	0,01	985
7	500	0,2	2,544	18304	360	1	turbulent	446,4	3,09 - 105	1,96 · 107
8	500	0,2	2,544	18304	2	180	»	0,044	4,85-103	3,07 · 107

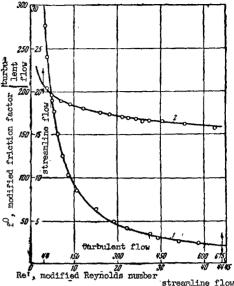


FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR fO UPON THE MODIFIED REYNOLDS NUMBER Re* BY THE FORMULA OF CHILTON AND COLBURN.

1 - streamline flow; 2 - turbulent flow

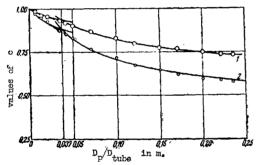


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS ${\bf c}$ UPON THE RATIO OF THE AVERAGE DIMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE ${\bf D}_{\bf p}/{\bf D}_{\bf tube}$ BY THE FORMULA OF CHILTON AND COLBURN. 1 - for streemline flow; 2 - for turbulent flow

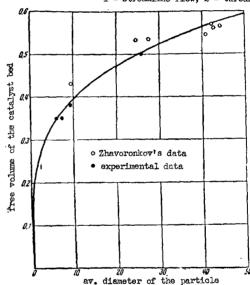


FIG. 3. DEPENDENCE OF THE FREE VOLULT OF THE CATALYST BED UPON THE AVERAGE DIMETER OF THE PARTICLES.

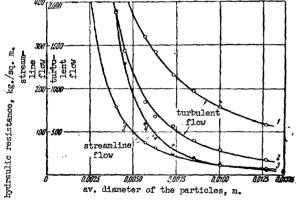
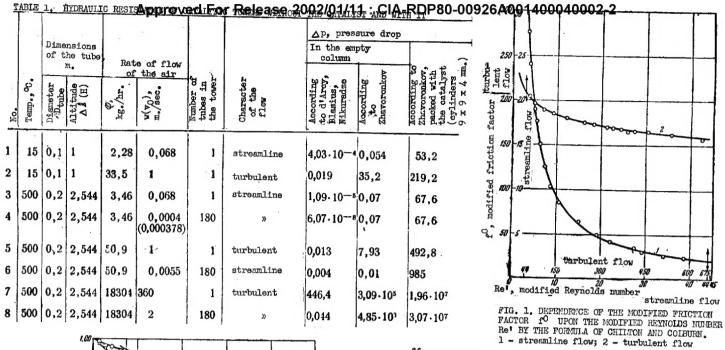


FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED $\Delta\,\mathrm{p}$ UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov. For streamline flow: 3 - according to Zhavoronkov; 4 - according to Chilton and Colburn.

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE DIAMETER OF THE GRAIN

No.	Type of packing	Shap e	Dimensions of the grains, mm.	Av. diam- eter of the grain, mm.	Free space
1* 2* 3	Glass rods Aluminosilicate catalyst Catalyst for con- version of CO	Cylinders Cylindrical tablets Tablets	5×5×8 9×9×4 11×11×6	6,0 7,8 9,3	0,35 0,35 0,38
5 6*	Vanadium catalyst Coke Glass granules Coke	" Irregular Pear-shaped Irregular	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	9,5 24,5 25,8 27,5	0,43 0,532 0,500 0,585
8 9 10 11	" Gravel Coke Andosite	" Spherical Irregular "	47,6×41,5×33,4 56,8×40,8×29 52×40,3×35,5 56×43,7×32,6	40,8 42,2 42,6 44,1	0,545 0,570 0,560 0,565



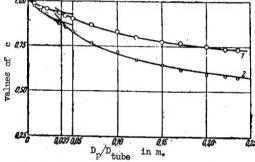


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS $\,$ UPON THE RATIO OF THE AVERAGE DIAMETER OF THE FARTICLES TO THE DIAMETER OF THE TUBE Dp/D tube BY THE FORMULA OF CHILTON AND COLBURN. 1 - for streamline flow; 2 - for turbulent flow

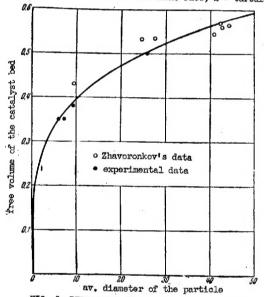


FIG. 3. DEPENDENCE OF THE FREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES.

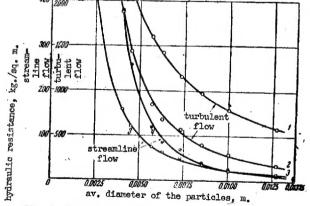
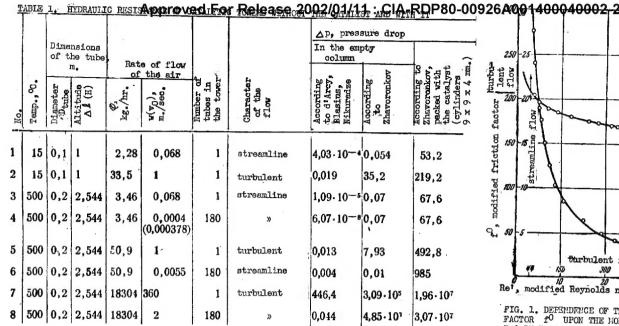


FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED \triangle p UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov. For streamline flow: 3 - according to Zhavoronkov; 4 - according to Chilton and Colburn.

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE

		DIAMETER OF THE	CRAIN		
No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diam- eter of the grain,	Free space
1*	Glass rods	Cylinders			
2*	Aluminosilicate	Cylindrical	$5\times5\times8$	6,0	0,35
	catalyst	tablets	9×9×4	!	
3	Catalyst for con- version of CO	Tablets	$\begin{array}{c} 9\times 9\times 4\\ 11\times 11\times 6\end{array}$	7,3 9,3	0,35 0,38
4	Vanadium catalyst	11	11×11×6,5	9,5	0,43
5	Coke	Irregular	20 6 34 05 0 34 10		
6*	Glass granules	Pear-shaped	$29.6 \times 25.8 \times 18$ $20 \times 20 \times 37.5$	24,5 25,8	0,532 0,500
7	Coke	Irregular	$35,6 \times 28,8 \times 18$	97.5	A 500
8			$47.6 \times 41.5 \times 33.4$	27,5 40,8	0,535 0,545
0	Gravel Coke	Spherical	56.8 × 40.8 × 29	42,2	0,570
11	Andesite	Irregular	$52 \times 40.3 \times 35.5$ $56 \times 43.7 \times 32.6$	42,6 44,1	0, 5 60



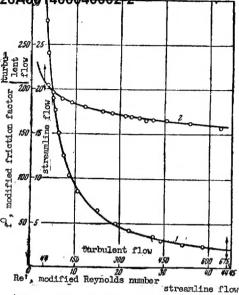


FIG. 1. DEFENDENCE OF THE MODIFIED FRICTION FACTOR ${\bf f}^{\bf O}$ UPON THE MODIFIED REYNOLDS NUMBER Re' BY THE FORMULA OF CHILTON AND COLBURN. 1 - streamline flow; 2 - turbulent flow

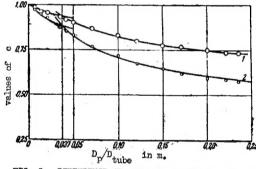


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS c UPON THE RATIO OF THE AVERAGE DIAMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE $D_{\rm T}/D_{\rm tube}$ BY THE FORMULA OF CHILTON AND COLBURN. $D_{\rm p}/D_{\rm tube}$ 1 - for streamline flow; 2 - for turbulent flow

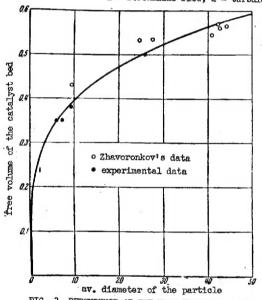


FIG. 3. DEPENDENCE OF THE FREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIALETER OF THE PARTICLES.

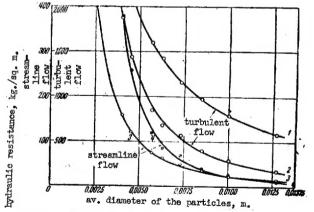
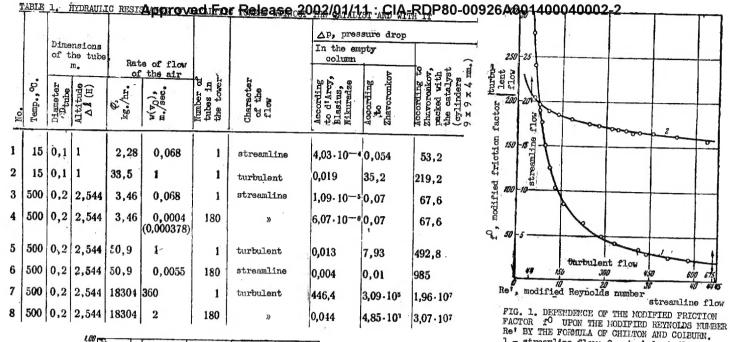


FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED \triangle p UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov.

For streamline flow: 3 - according to Zhavoronkov; 4 according to Chilton and Colburn.

TABLE 2. INTERDEPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE DIAMETER OF THE GRAIN

Cylinders Cylindrical	5×5×8		
tablets Tablets " Irregular Pear-shaped Irregular " Spherical	$9 \times 9 \times 4$ $11 \times 11 \times 6$ $11 \times 11 \times 6.5$ $29.6 \times 25.8 \times 18$ $20 \times 20 \times 37.5$ $35.6 \times 28.8 \times 18$ $47.6 \times 41.5 \times 33.4$ $56.8 \times 40.8 \times 29$	6,0 7,3 9,3 9,5 24,5 25,8 27,5 40,8 42,2	0,35 0,38 0,43 0,532 0,500 0,585 0,545 0,570
֡	Tablets " Irregular Pear-shaped Irregular "	Tablets $11 \times 11 \times 6$ " $11 \times 11 \times 6.5$ Irregular $29.6 \times 25.8 \times 18$ Pear-shaped $20 \times 20 \times 37.5$ Irregular $35.6 \times 28.8 \times 18$ Spherical $47.6 \times 41.5 \times 33.4$ 56.8 \times 40.8 \times 3.4	Tablets



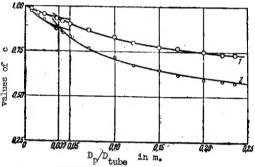
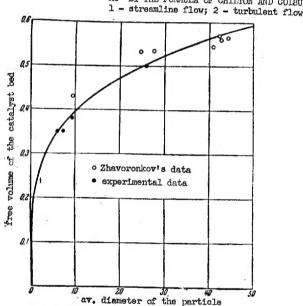


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS C UPON THE RATIO OF THE AVERAGE DIAMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE
Do D the BY THE FORMULA OF CHILTON AND COLBURN. 1 - for streamline flow; 2 - for turbulent flow



streamline flow

FIG. 3. DEPENDENCE OF THE FREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES.

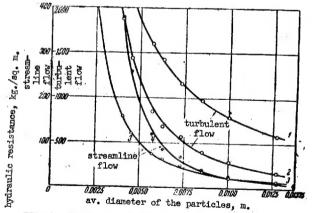
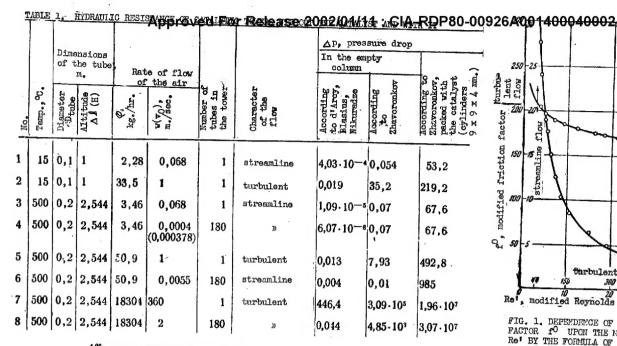


FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED Δ p UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov.
For streamline flow: 3 - according to Zhavoronkov; 4 according to Chilton and Colburn.

TABLE 2. INTERDSPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVI

		DIAMETER OF THE G	RAIN	E AVERAGE	
No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diam- eter of the grain,	Free space
1*	Glass rods	Cylinders			
2*	Aluminosilicate	Cylindrical	5×5×8	6,0	0,35
3	catalyst Catalyst for con- version of CO	tablets Tablets	$9\times 9\times 4$ $11\times 11\times 6$	7,3 9,3	0,35 0,38
4	Vanadium catalyst	Tf.	11×11×6.5	9,5	0,43
5 6*	Coke Glass granules	Irregular Pear-shaped	$\begin{array}{c} 29,6 \times 25,8 \times 18 \\ 20 \times 20 \times 37,5 \end{array}$	24,5 25,8	0,532 0,500
7 8 9 10 11	Coke Gravel Coke Andesite	Irregular "Spherical Irregular "	$\begin{array}{c} 35,6\times28,8\times18\\ 47,6\times41,5\times33,4\\ 56,8\times40,8\times29\\ 52\times40,3\times35,5\\ 56\times43,7\times32,6 \end{array}$	27,5 40,8 42,2 42,6 44,1	0,585 0,545 0,570 0,560 0,565



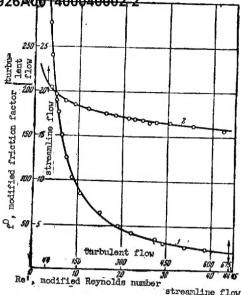


FIG. 1. DEPENDENCE OF THE MODIFIED FRICTION FACTOR fO UPON THE MODIFIED DEVALUE MANAGEMENT. FACTOR fO UPON THE MODIFIED REYNOLDS NUMBER Re' BY THE FORMULA OF CHILTON AND COLBURN. 1 - streamline flow; 2 - turbulent flow

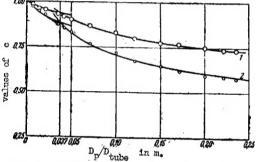


FIG. 2. DEPENDENCE OF THE COEFFICIENT OF THE EFFECT OF THE WALLS c UPON THE RATIO OF THE AVERAGE DIAMETER OF THE PARTICLES TO THE DIAMETER OF THE TUBE Dp/D tube BY THE FORMULA OF CHILTON AND COLBURN. 1 - for streamline flow; 2 - for turbulent flow

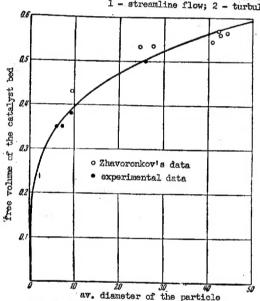


FIG. 3. DEPENDENCE OF THE FREE VOLUME OF THE CATALYST BED UPON THE AVERAGE DIAMETER OF THE PARTICLES.

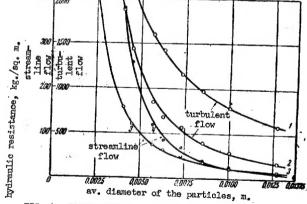


FIG. 4. DEPENDENCE OF THE HYDRAULIC RESISTANCE IN THE CATALYST BED Δ p UPON THE AVERAGE DIAMETER OF THE CATALYST GRAINS. For turbulent flow: 1 - according to Chilton and Colburn; 2 - according to Zhavoronkov. For streamline flow: 3 - according to Zhavoronkov; 4 -

TABLE 2. INTERDSPENDENCE BETWEEN THE FREE SPACE OF THE PACKING AND THE AVERAGE DIAMETER OF THE GRAIN

		I THE	GUATH		
No.	Type of packing	Shape	Dimensions of the grains, mm.	Av. diameter of the grain mm.	Free space
1*	Glass rods	Cylinders			
2*	Aluminosilicate	Cylindrical	5×5×8	6,0	0.35
3	catalyst Catalyst for con- version of CO	tablets Tablets	9×9×4 11×11×6	7,3 9,3	0,35 0,38
4	Vanadium catalyst	11	11×11×6,5	9,5	0,43
5 6*	Coke Glass granules	Irregular Pear-shaped	$29.6 \times 25.8 \times 18$	24,5	0,532
7 8	Coke	Irregular	$20 \times 20 \times 37,5$ $35,6 \times 28,8 \times 18$	25,8 27,5	0,500
9	Gravel Coke Andosite	Spherical Irregular	47.6×41.5×33,4 56.8×40.8×29 52×40.3×35.5	40,8 42,2 42,6	0,535 0,545 0,570 0,560
	MICOSTO		$56 \times 43,7 \times 32,6$	44,1	0,565